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ABSTRACT

This study examines the role of cognitive styles as they pertain to the learning of mathematics. Selected dimensions of cognitive style relevant to the learning of mathematics by two-year college students are identified and a resulting profile of cognitive style dimensions is analyzed in relation to mathematics achievement, aptitude, and attitude. In addition to specific conclusions offered for the three investigative questions posed in the problem statement, several general conclusions were suggested. Cognitive style appears to be related to learning mathematics at the two-year college level. Of the eight cognitive style dimensions investigated, three were related to the mathematics criterion variables (achievement and aptitude) in the correlative and predictive phases of the study. Three other dimensions were influential in the phase that the differential role played by cognitive style. (Author/MK)

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AN ANALYSIS OF SELECTED COGNITIVE STYLE DIMENSONS RELATED TO MATHEMATICS ACHIEVEMENT, APTITUDE, AND ATTITUDES OF TWO-YEAR COLLEGE STUDENTS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

By

John Roger Hinton, B.S., M.A.

* * * * *

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1980

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My program of graduate study and this research effort are dedicated to a caring, loving, encouraging, and sacrificing family. Both heartfelt and sincere thanks to my parents; and to my loving wife Barbara, and my patient son, Andy.

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INTRODUCTION

"Differences among learners in styles of perceiving, cognizing, and conceptualizing are probably as real as are differences in general intellectual ability and educational achievement." (Frederick & Klausmeier, 1970, p. 668) Be this an unproven assumption, or a valid statement, many educators do acknowledge the existence and the importance of individual difference variables in the teaching/learning process. As an example, the Guidelines for the Preparation of Teachers of Mathematics (1973) lists as one recommendation the attainment of competencies in "recognizing . . . individual differences between children as these differences pertain to the learning of mathematics." (p. 15)

One individual difference variable gaining increased attention and holding promise for those involved in the educational process is cognitive style. "While research on educational applications is still in its early stages, the evidence that research has already produced suggests that a cognitive-style approach may be applied with profit in a variety of educational issues." (Witkin et al., 1977, p. 1)

The overall goal of the present study is to examine--in a somewhat exploratory, yet analytical fashion--the role of cognitive styles as they pertain to the learning of mathematics. Selected dimensions of cognitive style relevant to the learning of mathematics by two-year

college students will be identified and a resulting profile of cognitive style dimensions will be analyzed in relation to mathematics achievement, aptitude, and attitude. The intent is to gain further insight into individual difference variables that affect the learning process.

CHAPTER I

General goals of educational research often cited in the literature are to understand the learning process better and to make the learning process both more effective and more efficient. To help understand human nature and to use this knowledge for increasing people's learning potential "... are no mean aspirations". (Cronbach, 1975, p. 126) Continual efforts of educational researchers are directed toward the discovery and identification of variables and/or relationships that help contribute to the attainment of the above general goals. In an attempt to assess and understand this act of the learning process, past research efforts have focussed on many areas including: learning theories, cognitive development, cognitive ability, cognitive measurement, cognitive processes, learning modalities, learning styles, individual differences, individual characteristics, etc..

Recently, a related area of investigation has received increased attention--especially as it relates to the educational process. (Allport, 1961; Glaser, 1972, 1973; Hodge, 1974; Kogan, 1971; Martens, 1976; Messick, 1970, Witkin & Moore, 1974) This new area represents a different kind of personological variable termed "cognitive style". "The concepts and methods derived from work on cognitive styles over the past two-and-a-half decades are being applied at an ever-increasing rate to research on problems of education." (Witkin et al., 1977, p. 1)

A proper perspective for this study on cognitive styles will be provided by outlining the evolution of the purposes of investigation, and by building a conceptual framework for the problem statement.

Purposes of Investigation

To begin, a research base was compiled by searching recognized bibliographical references such as ERIC, Education Index, Dissertation Abstracts International, and the Journal for Research in Mathematics Education. Information and bibliographies from papers presented at the AERA meetings were requested. In addition, citations (footnotes, bibliographical entries) in examined material were researched for reference to cognitive styles related to mathematics education. The following two purposes of investigation evolved from that search.

(1) To investigate the relationship of cognitive style to the learning of mathematics at the two year college level.

Substantial findings exist relating cognitive styles to the learning and teaching of mathematics at various other levels; and the implication is that cognitive styles have import at the college level. Yet, of over 250 references on cognitive style, relatively few studies using a college population were found. The relative sparsity of direct evidence hinders specific applicability of a cognitive style approach to the study of mathematics at the two year college setting.

Two specific studies held much promise for providing insight into the role of cognitive styles at the two year college level. Oen's investigation (1973) of the interaction of cognitive styles and types of learning experiences in vocational technical education was an attempt

to identify and use knowledge of learning styles needed in gaining technical skills and knowledge. However, the questionable selection of cognitive style dimensions and the research techniques used severely limited both the validity and the generalizability of the study.

On a much larger scale, Project Priority (Martens, (Ed.), 1976) supervised by the Two Year College Student Development Center in New York, attempted to pose and answer several critical questions. The relative lack of valid conclusions is in part reflective of design and sampling problems, and inconsistent analyses. The results are acknowledged as tentative with the value inherent not in what was shown, but in the implications suggested.

In this context, the intent evolved to extend present research findings to the two year college level, to validate tentative findings from existing studies, and to test several raised questions. To explore trends and to provide a research framework for ensuing investigations, the relationship of specific cognitive style dimensions to the global constructs of mathematics achievement, aptitude, and attitudes will be studied.

(2) <u>To examine the influence of cognitive style dimensions, not only in isolation, but in interaction with each other, as they relate to the learning of mathematics</u>

Again, of the many research studies investigated, relatively few examined the effects of more than one cognitive style dimension in relation to the learning of mathematics. Yet, if significant conclusions were reached, almost total credit was given to the single dimension under investigation. With the plethora of multivariate

techniques available, greater consideration can be given to possible interaction and assessment of unique contributions of individual cognitive style dimensions.

Noteworthy studies include those by Nelson (effects of analytic-global and reflective-impulsive cognitive styles on the acquisition of geometric concepts, 1972) and Koback (interactive effects of field dependence-independence and conceptual tempo on learning mathematics at the fifth grade level, 1975). Edgell (1973) and Pendleton (1975) each investigated the relationship of the cognitive style dimensions analytic-global and reflective-impulsive to focussing vs. scanning strategies on mathematical concepts. Martens (ed., 1976) investigated field dependence-independence, conceptual tempo, and the McKenney model dimensions of cognitive style.

An investigation of the research literature reveals those selected dimensions of cognitive style shown to have import for the learning of mathematics and those which need investigation. These include: field articulation (field dependence-independence), conceptual tempo (reflective-impulsive), locus of control, and the McKenney model dimensions. The intent of this study is to examine the relationship of each dimension, as well as possible interrelationships, to determine the relative independence of each and/or the unique contribution of each dimension to the learning of mathematics.

A subsequent outcome of this latter intent will provide some insight into the interrelationship of the cognitive style dimensions to intelligence. A sufficient number of studies (Black, 1977; Erginell, 1970; Fein, 1970; Frehner, 1973; Gordon, 1977; Satterly, 1976; and

Fennema & Behr, 1980) have raised pertinent questions and discussion on the possible confounding and/or interactive effects of intelligence to cognitive style dimensions.

Conceptual Framework

A conceptual framework for the problem statement can be built by discussing four relevant questions.

1) What is meant by the term "cognitive style"?

2) What properties distinguish cognitive styles from other learning related constructs, and what basic conclusions or generalizations have been drawn concerning these characteristics?

3) What are the implications for the teaching and learning of mathematics from the progress and development in cognitive style research?

4) How does the present study relate to the existing research on cognitive styles; and finally, what contribution to mathematics education can this research on cognitive styles make?

Questions 1 and 2 are discussed in the following paragraphs. A thorough discussion of question 3 is in the review of the literature (Chapter II). Question 4 was briefly discussed under the purposes of investigation in Chapter I, and discussion occurs again in Chapter II (Review of Literature) and in Chapter V (Summary, Conclusions, and Recommendations).

1) What is meant by "cognitive style"?

To be sure, researchers define and conceptualize the term "cognitive style" many different ways. However, a generic description

of the term which encompasses the essence of many of the definitions is given in an ERIC Thesaurus scope note: "Cognitive style refers to information processing habits which represent the learner's typical nature of perceiving, thinking, remembering, and problem solving." (ERIC, 1976, p. 308) Cognitive style is a characteristic mode of functioning (Witkin, 1976); it refers to consistency in the manner or form of cognition. (Messick, 1976)

2) What properties distinguish cognitive style from other learning related constructs, and what basic conclusions or generalizations have been drawn concerning these characteristics?

Perhaps the most essential characteristic is that "cognitive styles are (more) concerned with the form rather than the content of cognitive activity. They refer to individual differences in how we perceive, think, solve problems, learn, relate to others, etc." (Witkin et al., 1977, p. 5) The word "how" is the key to this process-oriented construct. This feature, according to Kogan (1971), distinguishes cognitive styles from abilities. "Abilities concern level of skill--the more or less of performance--whereas cognitive styles give greater weight to the manner and form of cognition." Cognitive styles are "theorized to serve as a heuristic of a high level that organizes lower level strategies, operations and inclinations, often including abilities in complex cognitive processes such as problem solving and learning." (Fennema & Behr, in press)

"Cognitive style has developed as a variable which is at the crossroads of an individual's cognitive and affective functioning." (Gray, 1974, p. 1) Cognitive styles permeate the totality of behavior.

Because cognitive styles are such a pervasive construct, they provide a more holistic view of how individuals learn.

Because cognitive styles stabilize in early adolescence and tend to remain stable over time, measurements of an individual's style are reliable and consistent. Viewed as unconscious habits (as by Messick), cognitive styles reflect the typical spontaneous, unplanned, responsive behavior to a situation. In this respect, cognitive styles are distinguished from strategies (learned, conscious, planned responses). In addition, being a personality related construct, the cognitive style of an individual may be measured with nonverbal perceptual techniques, instead of heavily verbal assessment instruments used to measure many cognitive and personality traits.

Ability dimensions tend to be unipolar and tend to vary from a low level to a higher level with emphasis on the maximum of performance. Cognitive styles are bipolar. Each dimension of cognitive style is a continuum with different, usually opposite, elements of cognitive functioning at each pole. This characteristic distinguishes cognitive style from intelligence and other ability dimensions. (Witkin et al., 1977, p. 16)

"Ability dimensions are fairly heavily value laden, whereas with cognitive styles there is none of the value differential. The value differential is a function of situation and task." (Martens, 1976, p. 4) Performance at either pole of the cognitive style continuum theoretically has no value attachment; each position has different implications for cognitive functioning, depending on the learning situation.

Definitions

1. Achievement: the skill or knowledge attained by an individual in the study of mathematics
2. Aptitude: an individual's ability or capacity to learn and understand mathematics
3. Attitude: an individual's attitude refers "to a learned predisposition or tendency ... to respond positively or negatively" toward mathematics (Aiken, 1970, p. 551)
4. Cognitive style: an individual difference variable which refers to self-consistent and characteristic modes of perceptual organization and conceptual categorization in cognition
5. Conceptual tempo: a cognitive style dimension having the two poles reflection and impulsivity. Conceptual tempo refers to an individual's attention to detail; and to the speed and accuracy with which alternative hypotheses are formulated, evaluated, and selected in problem situations

   reflective: a reflective individual displays long response times (latency) and low error scores; considerable time is taken to decide on the validity of hypotheses in a problem situation

   impulsive: an impulsive individual displays short response time (latency) and high error scores; solution hypotheses are selected quickly with minimal consideration for problem accuracy
6. Dimension: one of the elements or factors of this set of cognitive styles; also referred to as a style, trait, or attribute

7. Field articulation: a cognitive style dimension characterized by the two poles field dependent and field independent. Field articulation refers to an individual's ability to select relevant stimuli from an embedding context and to resist the interfering effect of the contextual stimuli

   field dependent: field dependent individuals are characterized as using a more global, undifferentiated approach to perceptual processing; perception is strongly dominated by the perceptual field

   field independent: field independent individuals are characterized as using a more analytical, differentiated approach to the perceptual process; items may be dealt with independently of the surrounding perceptual field

8. Intuitive-systematic: a cognitive style dimension affecting the information evaluation aspect of information processing. This dimension, related to problem solving, reflects the differences in approach

   intuitive: "Intuitive individuals more often consider solutions using trial-and-error, defining or redefining the problem, moving back to a solution and so on." (Nelson, 1974, p. 4)

   systematic: "Systematic individuals tend to approach a problem by devising a method or plan with specific, sequential steps to solutions." (Nelson, 1974, p. 6)

9. Locus of control: a personality construct refering to an individual's perception of the agency and the degree of control

over one's environment; control may be perceived as being internal or external

internal: a person at the internal end of the continuum perceives outcomes to be a consequence of one's own actions; an internal tends to be autonomous, inner directed

external: a person at the external pole believes that outcomes are due to fate, luck, and other forces beyond personal control; externals tend to be dependent, other directed

10. Preceptive-receptive: a cognitive style dimension affecting the information gathering aspect of information processing. This dimension refers to the perceptual process by which the mind organizes and codes the encountered stimuli

preceptive: Preceptive individuals "tend to use concepts and categories to code data. They look for relationships between stimuli so that they can efficiently catalogue information." (Nelson, 1974, p. 3)

receptive: Receptive individuals "are more sensitive to the stimulus itself. They focus on detail rather than relationships and try to derive the attribute of the stimuli from direct examination instead of fitting it to their precepts." (Nelson, 1974, p. 4)

Statement of the Problem

The purpose is to explore and examine the correlative, predictive, and differential nature of selected cognitive style dimensions as they relate to the learning of mathematics by two year college students.

More specifically, the relationship of the profile of the cognitive style dimensions: conceptual tempo, field articulation, locus of control, preceptive-receptive, and intuitive-systematic, will be analyzed with regard to mathematics achievement, aptitude for mathematics, and attitudes toward mathematics.

To assist in limiting the scope and to provide direction for the examination of the purported relationships, ensuing investigative efforts will focus on providing insight to three major questions:

1) Is there a significant correlational relationship between subsets of scores from students' cognitive style dimensions and subsets of scores from their achievement in mathematics, aptitude for mathematics, and attitudes toward mathematics?

2) Which cognitive style dimensions, separately or combined, are significant predictors of (a) achievement in mathematics, (b) aptitude for mathematics, and (c) attitudes toward mathematics?

3) Are cognitive style dimensions differentially exhibited in students in different mathematics sequences of study; and, if so, which cognitive style dimensions, separately or combined, significantly discriminate between students in the different mathematics sequences?

Assumptions

During the initial planning stages of the study, several assumptions were made. (References are made to assumptions acknowledged in prior research.)

1. The first and most important is that the construct of cognitive styles does have a referent in the real world. (Spitler, 1971)

2. The existence of cognitive styles has implications for learning mathematics. To be sure, cognitive styles have impact on other kinds of learning. However, it can be assumed that the learning of mathematics is in some ways unique and different from the learning of other subjects. (Spitler, 1971)

3. The dimensions of cognitive style can be defined and can be reliably measured. (Frederick & Klausmeier, 1970)

4. For each construct measured, the assessment instrument used is both valid and reliable.

5. Extraneous, yet possible confounding variables, such as age, sex, socio-economic status, race, motivational level, reading ability, and cooperative effort are distributed normally across the sample.

Limitations: The limitations of this investigation are as follows:

1. The sample will be limited to two year college students in the following programs of study: accounting, business data processing, general business management, electronic engineering, medical laboratory, and nursing. Therefore, the study's results will have limited potential for generalizability.

2. Random sampling was not strictly adhered to in selecting the mathematics sequences of study from the population in general, nor in selecting the students from each particular sequence.

3. Since students were aware of participation in a research project to determine their "learning style", the possibility of

Hawthorne effect exists.

4. A practice effect in testing may have influenced the results since each subject completed eleven assessment instruments.

Hypotheses

Questions raised in the problem statement, in the pilot study, and in the review of the literature led to the formulation of several hypotheses. Stated in null form, the specific research hypotheses to be tested are listed under three areas.

To examine the inter-correlative nature of the cognitive style dimensions as well as the correlational relationship of the cognitive style dimensions to mathematics achievement, aptitude, and attitudes, the following hypotheses were posed:

Hypothesis 1: None of the following variables will exhibit first order correlations with any of the others in a significant manner:

The student's position on each cognitive style dimension:

(a) field articulation as measured by the Group Embedded Figures Test
(b) conceptual tempo as measured by the Matching Familiar Figures Test
(c) locus of control as measured by the Adult Nowicki-Strickland Internal External Scale
(d) preceptive-receptive as measured by the Symbols Test and Identical Pictures
(e) intuitive-systematic as measured by Scrambled Words and Following Directions

and the student's:

(f) grade in the first required mathematics course
(g) mathematics achievement as measured by the Columbus Technical Institute Mathematics Placement Tests
(h) aptitude for mathematics as measured by the Mathematics Aptitude Test
(i) attitude toward mathematics as measured by the Revised Math Attitude Scale

(j) measure of intelligence as determined by Advanced Progressive Matrices

Hypothesis 2: The subset of scores from the cognitive style dimensions will not exhibit a significant canonical correlation with the subset of scores from mathematics achievement, aptitude, and attitudes.

Partial correlations from regression analysis will allow further insight into the correlative and the predictive nature of the cognitive style dimensions. The overall contribution of cognitive style dimensions, as well as the unique contribution of each dimension individually, may be ascertained by multiple correlational analysis. To that end, the following two hypotheses were posed:

Hypothesis 3: None of the cognitive style dimensions will make a significant contribution to the multiple correlation with:

(a) mathematics achievement
(b) aptitude for mathematics
(c) attitudes toward mathematics

Hypothesis 4: Including the measure of intelligence, in addition to the cognitive style dimensions, will not significantly change the multiple correlations in Hypothesis 3.

Both the literature and pilot study suggest further investigation of the differential nature of the cognitive style dimensions. To determine these differences, as well as to substantiate the validity of the predictor variables across different mathematics sequences, the variability of scores was analyzed with multivariate techniques. Multivariate analysis of variance and discriminant analysis were used to further test the following three hypotheses:

Hypothesis 5: For each of the cognitive style dimensions

(a) field articulation

(b) conceptual tempo
(c) locus of control
(d) preceptive-receptive
(e) intuitive-systematic

there will be no significant difference between groups of students in the different mathematics sequences.

Hypothesis 6: For each of the cognitive style dimensions

(a) field articulation
(b) conceptual tempo
(c) locus of control
(d) preceptive-receptive
(e) intuitive-systematic

there will be no significant difference between groups of students in the different mathematics sequences, provided intelligence is partialled out.

Hypothesis 7: The profile of cognitive style dimensions will not significantly discriminate between students in different mathematics sequences of study.

Overview of the Dissertation

The intention of Chapter I was to familiarize the reader with an understanding of the problem being investigated by providing a conceptual framework for the problem statement which extends through to the formulation of the research hypotheses.

Chapter II presents a review of the related literature and findings of pertinent studies.

The research design and procedures used during this study are discussed in detail in Chapter III. This chapter delineates the selection of the cognitive style dimensions, the pilot study, the questions for investigation, instrumentation, the population and

sample, data collection, summary of hypotheses, and methods of analysis of the data.

Analyses of the data, together with findings, are reported and discussed in detail in Chapter IV.

A summary of the study, conclusions, interpretations, and recommendations for further research are presented in Chapter V.

CHAPTER II

REVIEW OF LITERATURE

Introduction

In the formation of a conceptual framework delineated in Chapter I four questions were posed--and serve--as guidelines for this investigation:

1) What is meant by the term "cognitive style"?

2) What properties distinguish cognitive styles from other learning related constructs, and what basic conclusions or generalizations have been drawn concerning these characteristics?

3) What are the implications for the teaching and learning of mathematics from the progress and development in cognitive style research?

4) (a) How does the present study relate to the existing research on cognitive styles? and (b) What contribution to mathematics education can this research on cognitive styles make?

While questions 1 and 2 were discussed in Chapter I, Chapter II attempts to provide insight into questions 3 and 4. The following main sections serve to organize Chapter II.

A. General overview of cognitive styles

B. Definition of cognitive style

C. A specific illustration of one dimension of cognitive style (field articulation)

D. Compilation of cognitive style dimensions

E. State of the art and needed research

F. Relevance of cognitive styles to the learning of mathematics

1. Various cognitive styles and the implications for mathematics education (Spitler)

2. Research regarding field articulation, conceptual tempo, locus of control, and the McKenney model dimensions

3. Additional cognitive style research related to mathematics learning/teaching

G. Purposes of investigation

General Overview of Cognitive Styles

Cognitive style has been introduced and reintroduced in the psychological literature over a period of time dating back to the German psychologists at the turn of the century. In the 1930's, style (entire pattern of responses) was used in the study of consistency and predictability of personality. Allport (1937) used "style" to describe consistencies or patterns in day-to-day activities. While this idea of consistencies is employed in the current usage of cognitive style, the emphasis then was more on the personal-social domain--as opposed to the current emphasis on cognitive-perceptual functioning. "In the last few years there has been renewed interest in cognitive psychology in general and in cognitive style in particular." (Goldstein & Blackman, 1978, p. vii)

While thousands of studies involving cognitive styles could be cited, the volume of literature is deceiving in that "cognitive style" has been an eclectic "all encompassing" descriptor. (In an ERIC Thesaurus scope note, "cognitive style refers to information processing habits which

represent the learner's typical nature of perceiving, thinking, remembering, and problem solving." (ERIC, 1976, p. 308)) Similarities can be made, and have been made, between the construct cognitive style (characteristic ways in which individuals conceptually organize information) and many earlier concepts--such as silent organization (Gestaltists), cognitive maps (Tolman), schemata (Piaget), hierarchical organization (Lewin), and structure of intellect factors (Guilford).

While the term cognitive style is found most frequently in the psychology literature, educators prefer the term learning style. "The difference is largely one of focus rather than substantive meaning; presumably educators are more interested in 'individual differences in cognitive organization and functioning (Ausubel, 1968)' as they pertain to classroom teaching and learning. In addition, learning style may include affective factors, as well as preferences for certain kinds of learning environments, sensory modalities, and interactive modes." (Baker, 1977, p. 14)

As an aid in limiting the diverse referents for cognitive style--and also as a future guide to sort through the proliferation of dimensions of cognitive style--the following working definition has been designed by the investigator from current researchers' conceptualizations of cognitive style.

Definition

Cognitive style is an individual difference variable which refers to self-consistent and characteristic modes of perceptual organization and conceptual categorization in cognition.

As a simplified illustration of the terms "perceptual organization and conceptual categorization", reference is made to several items from the Conceptual Style Test (Kagan et al., 1964). Differences in the stimulus characteristics to which a person initially attends, or in the aspects of the stimuli that are initially selected for labelling may be significant individual differences in information processing.

For each item in Figure 1 the subject is asked to "pick out two pictures that are alike or go together in some way" and to state the basis for the grouping. Different illustrations of perceptual organization and conceptual categorization from several items on the Conceptual Style Test might include: "the watch and ruler have numbers", "the house and pipe have smoke coming out", "people with hats on", or "the man wears the watch".

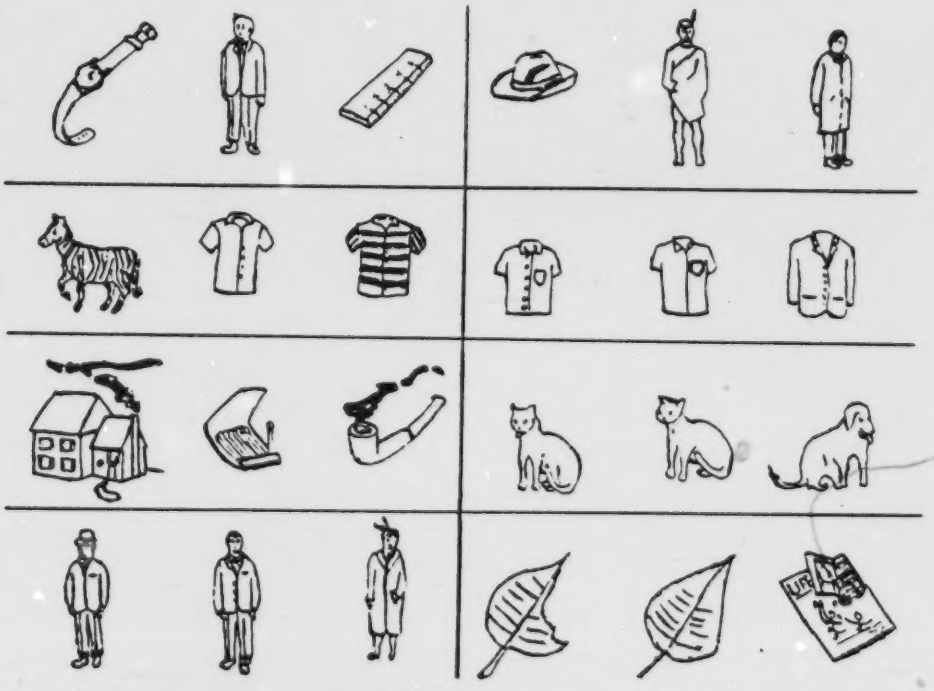


Figure 1. Sample items from Conceptual Styles Test (reduced 74%)

As illustrations where "perceptual organization and conceptual categorization" might be relevant to learning mathematics situations, consider the following "word problem":

> A boat travels at a constant rate in still water. It travels downstream 18 miles in two hours; the return trip requires six hours. Find the rate of the boat in still water and the rate of the current.

or the following geometry problem: (see Figure 2)

Given: $\overline{YB} \perp \overline{AC}$; $AX = CX$; $AB = CB$.
Prove: $\angle AXY = \angle CXY$.

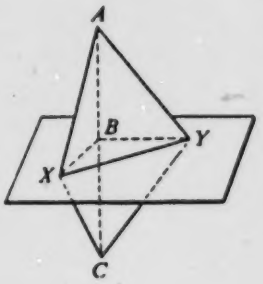


Figure 2. Illustration of information processing-sample geometry problem

Success, in large part, depends upon which stimuli are initially attended to and how the aspects of the stimuli are conceptually categorized and related.

Problem solving in general requires a degree of "perceptual organization and conceptual categorization". "Problem solving involves at least three distinct processes that occur in the following sequence: the initial categorization of information, storage of the encoded information, and the imposing of transformations or mediational elaborations upon the encoded material." (Kagan et al., 1964, p. 1)

In addition to the current emphasis on cognitive-perceptual functioning, the evolutionary process in the study of cognitive style shows the emphasis has more recently shifted from the earlier content laden research (i.e. on authoritarianism, Sanford, 1954) to the more avowedly stylistic approaches represented in the work of George A. Kelley (1970). Other examplars of the stylistic approach would have to include the works of Witkin et al. (1962), field dependence (global) and field independence (analytic); Broverman (1960), conceptual vs. perceptual dominance; Gardner et al. (1959), cognitive control patterns; and Kagan, Moss, & Sigel (1963), descriptive, relational, and categorical.

"Especially as attempts are made to understand the cognitive processes that underlie academic performance, attempts have been made to explain differences in the learning processes by demonstrating that persons consistently adopt a characteristic (stylistic) approach to the learning task." (Witkin, 1975, p. 61) More and more attention--and research literature--have been focussed on the stylistic dimensions in cognitive tasks: Faterson, 1962; Kogan, 1976; Landfield, 1977; Witkin & Dyke et al., 1962; and Messick and associates, 1976.

Because the reference in cognitive style research is to the characteristic approach an individual brings to a wide range of situations, the term "style" is used; because this characteristic approach includes handling both perceptual and intellectual tasks, the term "cognitive" is used. Despite the fact that these self-consistent modes of functioning pervade an individual's personality and social behavior, the narrow label "cognitive style" persists. Viewed in this broader sense, a more appropriate designation according to Witkin and Moore (1974) would be "personal style." In this research the more

narrow label is used since the primary focus is on the perceptual and conceptual domain--not the social or personality domain.

Presumably an individual has many characteristic approaches in learning tasks--or, many elements may comprise a characteristic approach; therefore, the plural "cognitive styles" is often used. However, in this investigation, a more common practice--as well as more conceptually appealing--will be used. The various approaches, or the factors that comprise an approach, will be referred to as "dimensions." An individual's cognitive style, then, will be the composite set of all such dimensions.

Specific Example

Field articulation will be chosen from the multitude of dimensions to illustrate a specific dimension; field articulation was chosen because it has one of the largest research bases.

> Field articulation refers to the "extent to which a person perceives part of a field as discrete from the surrounding field as a whole, rather than embedded in the field; or the extent to which the organization of the prevailing field determines perception of its components; or, to put it in everyday terminology, the extent to which the person perceives analytically. Because at one extreme of the performance range perception is strongly dominated by the prevailing field, that mode of perception was designated 'field dependent'. At the other extreme, where the person experiences items as more or less separate from the surrounding field, the designation 'field independent' was used. Because scores from the test of field-dependence-independence form a continuous distribution (see Figure 1) these labels reflect a tendency, in varying degrees of strength, toward one mode of perception or the other." (Witkin et al., 1977, p.6,7)

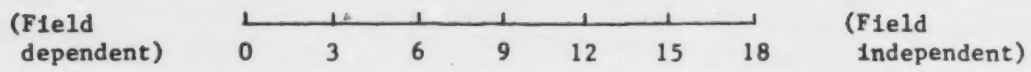
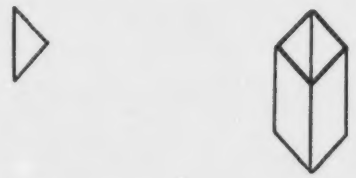
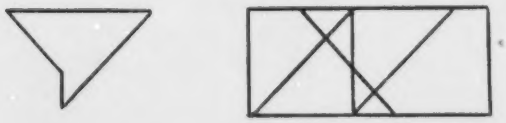


Figure 3
Illustration of Possible Score Distribution for GEFT

The Group Embedded Figures Test (GEFT) is one instrument to measure field dependence-field independence. A sample practice item from the test follows. The subject is instructed to find, and trace, the simple figure within the complex figure on the right.



A more difficult example would be:



The more items correctly traced on either the Embedded Figures Test (EFT) or the Group Embedded Figures Test (GEFT), the greater the tendency toward the 'field independent' end of the continuum.

"In particular to mathematics education, Witkin believes that this cognitive style appears in problem solving behavior or mathematical reasoning, particularly in those problems which require disembedding a critical portion and restructuring the problem materials so that the disembedded portion is utilized in a different way." (Fennema & Behr, in press)

Compilation of Cognitive Style Dimensions

A listing of the most frequently mentioned cognitive style dimensions was compiled from a review of the literature (see Table 1). The compilation drew heavily from earlier listings of related constructs by Feshbach - individual difference variables (1968); by Williams - cognitive preferences (1975); and by Messick - approaches to the study of cognitive styles (1976). Only dimensions of cognitive style, as conceptualized herein, were selected. For this reason, several notable works were excluded (i.e. 17 of the 18 categories delineated by Dunn and Dunn (1975) on learning styles--these were construed more as elements that affect a learner's style than learning style dimension).

Cognitive Style Dimension Models

Several researchers/authors have attempted to integrate several dimensions into a more unified model. Three such models are presented, each with different origins, structures, and applications.

"Messick (1970) lists and describes nine separate cognitive dimensions that have been the object of systematic theoretical and empirical examination by various researchers". (Martens, 1976, p. 3) The nine dimensions, each bi-polar, include field dependence-field independence; cognitive complexity vs. simplicity; scanning; breadth of categorizing; conceptualizing style; reflectiveness vs. impulsivity; leveling vs. sharpening; constricted vs. flexible control; and tolerance for unrealistic experiences.

Table 1

Listing of Cognitive Style Dimensions

	Cognitive Style Dimension	Investigator(s)/author(s)	
1.	Visual	Riessman; Hill and Nunney	
2.	Oral - Aural	Riessman; Hill and Nunney	
3.	Physical/tactile	Riessman; Hill and Nunney	
4.	Descriptive	Kagan, Moss and Sigel	conceptual styles
5.	Relational-contextual	Kagan, Moss and Sigel	conceptual styles
6.	Inferential-categorical	Kagan, Moss and Sigel	conceptual styles
7.	Modes of thought	Taba, LaVine, and Elzer	
8.	Perceptual/conceptual categorization of external environment	Davis	
9.	Personal ways in which individuals process information in learning new concepts & principles	DeCecco	
10.	Rigid inhibited	Rosenburg	
11.	Undisciplined	Rosenburg	
12.	Acceptance anxious	Rosenburg	
13.	Creative	Rosenburg	
14.	Impulsive	Kagan	
15.	Reflective	Kagan	
16.	Analytic/non-analytic	Kagan	
17.	Auditory	Hill and Nunney	→ Elements of Hill's Model
18.	Olfactory	Hill and Nunney	→ Elements of Hill's Model
19.	Savory	Hill and Nunney	→ Elements of Hill's Model
20.	Proprioceptive	Hill and Nunney	→ Elements of Hill's Model
21.	Code - empathetic	Hill and Nunney	→ Elements of Hill's Model
22.	Code - esthetic	Hill and Nunney	→ Elements of Hill's Model
23.	Code - ethic	Hill and Nunney	→ Elements of Hill's Model
24.	Code - histrionic	Hill and Nunney	→ Elements of Hill's Model
25.	Code - kinesics	Hill and Nunney	→ Elements of Hill's Model
26.	Code - kinesthetics	Hill and Nunney	→ Elements of Hill's Model
27.	Code - proxemics	Hill and Nunney	→ Elements of Hill's Model
28.	Code - synnectics	Hill and Nunney	→ Elements of Hill's Model
29.	Code - transactional	Hill and Nunney	→ Elements of Hill's Model
30.	Realistic	Holland	
31.	Investigative	Holland	
32.	Artistic	Holland	
33.	Social	Holland	

Table 1 (cont.)

Listing of Cognitive Style Dimensions	
34. Enterprising	Holland
35. Conventional	Holland
36. Conservative focussing	Bruner
37. Focus gambling	Bruner
38. Successive scanning	Bruner
39. Simultaneous scanning	Bruner
40. Analytic - active	Witkin, Wallach
41. Global - passive	Witkin, Wallach
42. Concrete/symbolic	Bruner, Oliver, and Greenfield
43. Structured vs. unstructured	Nelson, Oen, and Banks
44. Perceptual strengths and styles	Dunn and Dunn — Sensory modality preferences
45. Iconic representation	Bruner, Oliver, and Greenfield
46. Symbolic representation	Bruner, Oliver, and Greenfield
47. Enactive representation	Bruner, Oliver, and Greenfield
48. Field dependent	Witkin, Osipow
49. Field independent	Witkin, Osipow
50. Leveling - sharpening	Gardner, Mariarty
51. Constricted - flexible	Smith, Klein
52. Conceptual differentiation	Gardner, Schoen
53. Tolerance for unrealistic experiences	Klein, Gardner, Schlesinger
54. Conceptual vs. perceptual motor dominance	Broverman
55. Automatization	Broverman
56. Scanning	Gardner, Moriarty
57. Contrast Reactivity	Gardner, Lohrenz, Schoen
58. Category width	Bruner, Goodnow, Austin, Tajfel
59. Cognitive complexity	Kelly, Bieri
60. Integrative complexity	Harvey, Hunt, Schroder
61. Receptive - preceptive	McKenney, Nelson
62. Systematic - intuitive	McKenney, Nelson
63. Converging - diverging	Cronbach, Wallach, Kogan
64. Compartmentalization	Messick and Kogan
65. Conceptual articulation	Bieri
66. Risk taking vs. cautiousness	Kogan and Morgan

In Individuality in Learning, Messick (1976) modified these nine categories, and increased the total to 19. "This reflects both increasing research interest in cognitive style and Messick's continuing attempt to organize and integrate a wide variety of research efforts." (Goldstein and Blackman, 1978, p. 4)

McKenney's model (1972) is derived primarily from research efforts of Witkin and Bruner. This model is a two dimensional model of information processing dealing with information gathering and information evaluation. Figure 4 depicts the dimensions and the labels attached to each pole.

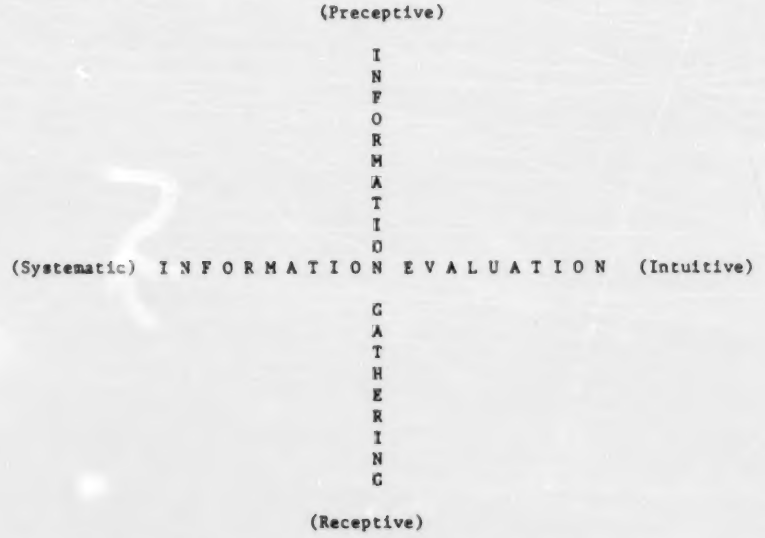


Figure 4. Dimensions of the McKenney Cognitive Style Model

Most people can be described in terms of a cognitive operating space; an individual's preferred mode on each of the two dimensions would locate that person in one of four categories: intuitive preceptive, intuitive receptive, systematic preceptive, or systematic receptive.

elements of common interest in cognitive style research, frequently the findings are not comparable because of lack of uniformity of definitions; and disagreement on approaches, on conceptualizations, on terminology, on models, on measuring instruments, or on constructs or dimensions studied.

The existent state of the art, then, is a body of literature from which it is difficult--at best--to extract general principles. Kagan and Henker (1966) point out the need for systematization at the levels of theory and research; studies designed to relate the variables used by one investigator to those used by other investigators as needed. One of the intentions of this study is to research the cognitive style variables (field articulation, Witkin; conceptual tempo, Kagan; information processing model, McKenney; locus of control, Norwicki) used by several different investigators with the goal of providing one step toward unification of cognitive style research.

Current research in cognitive styles, in main, seeks correlations between an individual's extreme position on a specific cognitive style continuum (e.g. field dependence-field independence) and that individual's ... performance on intellectual tasks (i.e. subtests of Weschler, reading, mathematics, etc.). Letteri (1977) raises the issue that these dichotomous correlations may not provide a complete picture of the cognizing event--especially if two or more cognitive style continuums are actually involved. If learning is viewed as a multifaceted process, the contention exists that a "multivariate" approach would be more insightful, and valid. An individual's cognitive style <u>profile</u> would make it possible to study

interrelationships between continuums (cognitive style dimensions) and their combined impact on performance levels in learning tasks. The second intention of this study is to research several selected cognitive style dimensions in a multivariate sense, investigating the interaction of the variables among themselves and also as they relate--overall contribution and unique contribution--to the global constructs of mathematics achievement, aptitude, and attitudes.

3) What are the implications for the teaching and learning of mathematics from the progress and development in cognitive style research?

To provide a framework for selecting cognitive style dimensions, in addition to showing the relevancy of cognitive style research to the learning and teaching of mathematics, question 3 was posed. Discussion is organized under three subtopics. First, the comprehensive work of Spitler (1971), "Investigations of Various Cognitive Styles and the Implications for Mathematics Education" will be summarized briefly. The work provides an excellent introduction to cognitive styles, a thorough review of the literature, and a demonstration of the relevancy of the cognitive style dimensions field articulation and conceptual tempo to mathematics education.

Second, after the summary of Spitler's work, several major dimensions related to learning and teaching mathematics will be discussed in detail. Finally, to provide further evidence of the cognitive style variables to the learning of mathematics, additional research findings are reported.

In his synthesis of the research literature, Spitler delineated three major constructs of cognitive style. After presenting an in-depth analysis of each major researcher's position on these "variables of cognitive consistency," Spitler then examines each construct for its relevance to the overall and specific organization of curriculum materials and teaching strategies. These three constructs are summarized, highlighted by Spitler's observations.

(1) the construct field articulation; major researcher, Witkin

From the development of the basic notions of mathematics from elementary school through high school, the style demands of learning mathematics tend to favor the cognitive style of field independent learners. These subjects tend to be more aware of the elements of complex stimuli and are more able to deal with patterned stimuli in an analytical manner than field dependent subjects. "Numbers of studies link mathematics aptitudes and achievement with field independence." (Spitler, 1971, p. 66)

In the development of the basic notions of number, space, geometry, and logic, as suggested by Piaget, field independent youngsters have distinct advantages:

(a) Perception of detail plays an important role in notions of conservation of discrete quantities, which are basic to a child's understanding of number.

(b) Field independent children tend to reach the stages of development sooner than their field dependent counterparts. "It may be that a given degree of field independence is necessary for a child to move from one

stage of development to another." (Spitler, 1971, p. 48)

(c) Perception plays a significant role in children's understanding of spatial and geometric concepts. Most forms of spatial perception seem directly related to field dependence-independence.

Mathematics curricula tend to require or favor a field independent style in the articulation of perceptual detail and the attention to such detail (i.e. precise and economical nature of mathematics symbolism, pictorially presented problems, graphs, approach to geometrical problems, proofs, etc.). Patterned stimuli in the development of definitions, concepts, and algorithms tend to favor the analytic manner of field independent students. "The ability to shift psychological sets in thinking and the ability to reason inductively on literal or numerical patterns is also significantly related to field independence." (Spitler, 1971, p. 171)

The implications for mathematics education begin with an acknowledgement and assessment of the field dependent style found in the classroom. Then, comes possible training for greater field independence along with development of instruction methods more suited to field dependent learners and the production of curricular materials whose topics have been placed at the appropriate grade level.

(2) the construct cognitive controls; major researcher, Gardner

Of six cognitive controls, two have special importance for the learning of mathematics: leveling-sharpening and tolerance for unrealistic experience. Sharpeners differ from levelers in the higher degree of articulation of recall. Mathematics programs involving more

rigorous logic demand memory, especially precise recall, of number facts, definitions, axioms, algorithms, theorems, and mathematical notation. Such programs would seem to favor a sharpening cognitive control. If this demand is pervasive throughout secondary school, the leveler is at an extreme disadvantage in problem solving and the exercise of various other heuristics of mathematics.

A curriculum as advocated by Polya (1962) or Kline (1966), with a reduction in the number of mathematical concepts to be learned and retained, and with a greater emphasis upon problem solving and heuristics would be more efficient for levelers. Care should be taken in the placing and timing of indirect proofs in the curriculum for levelers. Classroom changes might include aiding levelers by allowing them to use lists of definitions, assumptions and theorems, and possibly "open book" exams.

(3) the construct conceptual tempo; major researcher, Kagan

Conceptual tempo is operative in various problem situations containing high response uncertainty. Reflective, as opposed to impulsive, learners tend to go slower and be more accurate.

A reflective child is able to inhibit his impulsive responses and consider alternative hypotheses. According to Piaget (1965), the ability to coordinate two or more aspects of a stimulus differentiates the child at the concrete operational level from the child at the pre-operational level. Such a reflective conceptual tempo also seems helpful for acquiring the concepts that are the basic foundations of number, space, and geometry.

Discussion of the major dimension - Field Articulation

Witkin et al. (1977) in a recent article, "Educational Implications of Cognitive Style", focusses primarily on the cognitive style field dependence-independence, but makes several implications not found in Spitler's work. Main points of Witkin's article are summarized under the three areas: concept learning, teaching, and guidance and counseling.

Concept learning In relation to concept learning, research indicates cognitive styles exhibit a differential learning approach. Field dependent students, being more likely to require externally defined goals and reinforcement than the field independents, have greater difficulty in learning material lacking inherent structure. Field independent students are more likely to provide the mediating structural rules needed to facilitate learning. If alternative methods of instruction are available, the contention is the field dependent students may function more efficiently with programmed instruction, or in learning settings with a greater degree of structure.

In problem-solving strategies, field dependent subjects may need more explicit instruction than field independents who seem to perform better when they develop their own strategies. As progress toward more precise specification of field dependent-independent behavior is made, suggestions emerge "for ways of teaching students to use problem solving strategies most appropriate to their styles, and even to shift to strategies more suitable for the task at hand than their preferred strategies." (Witkin et al., 1977, p. 15)

From studies of concept attainment, the work of Nebelkopf and Dreyer (1970) substantiate the assertion that field independent students are more likely to assume an active role and use the hypothesis testing model of Bruner, Goodnow and Austin (1956), (an active role); whereas field dependent subjects tend to use a more passive or spectator role. In concept learning there also seems to be a differential treatment of cue salience. Field independent subjects learn concepts more rapidly when the salient cue is irrelevant to the definition of the concept, while field dependent subjects, particularly responsive to the dominant arrangement of the given perceptual field, tend to ignore some (presumably non salient) attributes. Some evidence exists that suggests field dependent students may be aided in overcoming their domination by cue salience. (Witkin et al., 1977, p. 2)

Teaching If the intent of education is to learn concepts, as well as facts, the role of field dependence-independence deserves attention both to understand the learning process and to enhance the teaching process.

In the area of individualization of instruction, a strong movement exists to tailor instruction to fit particular students or small groups of students. (Coop & Sigel, 1971) In an article by Brennan and Post, 1977, they claim, "a major goal of mathematics education is to match instructional procedures to particular types of problem situations and to particular types of student aptitudes." (p. 158) Several matching strategies that adapt instruction for the particular styles of students have been suggested. Hester and Tagatz (1971) have shown that an individual can be instructed in a manner consistent with one's

cognitive style. Messick (1976) suggests four possible alternatives: remedial, compensatory, capitalization, and challenge. The last suggestion is somewhat analagous to a mismatch strategy. While Witkin does discuss the cognitive style match-mismatch, he also strongly urges caution to be exercised until research provides further insight into the complexity of these relations.

Guidance and counseling Beyond its implications for concept learning and teaching, field dependence-independence has potential value for guidance and counseling. Post secondary teachers could also use the following information in the teaching process. Regarding educational-vocational choices and interest, field independent students tend to gravitate toward sciences, mathematics, and engineering--professions emphasizing analytical, structuring learning skills; field independent students also achieve significantly better in these domains than field dependent students who prefer more socially oriented careers. In general, within mathematics Stone (1976) found field independence related more to application and problem solving than to computation.

Being relatively stable over time, cognitive style dimensions could offer practical suggestions for counselors and instructors in dealing with students inclined to enter a field demanding opposing style traits (e.g. an area requiring extensive mathematics preparation for field dependents). Because cognitive styles tend to be neutral in character, information about a student may be communicated directly to that person in a non-threatening and helpful manner.

Discussion of the major construct--Conceptual Tempo

The construct of conceptual tempo (reflective-impulsive) was originally introduced by Kagan, Rosman, Day, Albert, and Phillips (1964). Initially concerned with an individual's consistency in speed with which decisions are made under conditions of uncertainty, "reflection versus impulsivity involves individual consistencies in the speed and adequacy with which alternative hypotheses are formulated and information processed, with impulsive individuals tending to offer the first answer that occurs to them, even though it is frequently incorrect, and reflective individuals tending to ponder various possibilities before deciding. This dimension is thus mainly concerned with the degree to which an individual reflects on the validity of his hypotheses for solutions in problems that contain response uncertainty (Block, Block, and Harrington, 1974; Kagan and Kogan, 1970; Kagan and Messer, 1975; Kagan, Rosman, and others, 1964; Yando and Kagan, 1968)". (Messick, 1976, p. 19)

In Individual Differences and the Learning of Mathematics, Fennema and Behr contend that "since a desirable behavior in mathematics is to formulate, reflect upon, and reformulate hypotheses, this construct (conceptual tempo) warrants study in the context of mathematical learning". (in press)

"A reflective child is able to inhibit his impulsive responses and consider alternative hypotheses". (Spitler, 1970, p. 117) If this is the case, Shantz and Sigel (1967) make a strong argument for a relationship between a reflective conceptual tempo and the acquisition of concepts that are the basic foundations of number, space, and

geometry. For example, in attainment of conservation of continuous and discontinuous quantities, and addition composition of classes, coordination of several aspects of a stimulus is required. A reflective conceptual tempo would allow a child to consider the alternative hypotheses suggested by these details. However, this apparent relationship, as suggested by Shantz and Sigel, needs more empirical evidence for validation.

From research findings, reflective children evidence (a) greater recall (Kagan, 1966), (b) greater memorization ability (Kagan, 1966), and (c) greater reasoning ability (Kagan, Pearson, & Welch, 1966) than impulsive children. In a study on concept attainment at the formal level, reflective subjects were able to infer concepts better than impulsive subjects. (Nelson, 1972)

Throughout the mathematics curriculum, K-12, and beyond, both impulsive and reflective conceptual tempo are demanded; "that is, computational tasks demand some speed of response (impulsivity) while mathematics problem solving and reasoning demand thought and criticalness (reflectivity)". (Spitler, 1970, p. 123) A reflective demand in learning mathematics would be needed, particularly when discovery-oriented learning tasks are used. (Kagan, et al., 1966)

When the Matching Familiar Figures Test (MFFT) is used to measure conceptual tempo, frequently in research only the time measure is used. Kogan and Messer (1975) note that both speed and accuracy are needed to define reflectivity-impulsivity. Mitchell and Ault (1977) claim both MMFT errors and latency are often equally important as predictors of problem solving performance. In a study by Fein (1970), when error

scores and time scores were used to define reflective and impulsive groups, the reflective students obtained significantly higher abstract reasoning scores (APM II) than impulsive students. Both error scores and latency to first response are used in this present study.

Finally, as Spitler points out, a reflective conceptual tempo may be one of the basic determinants of an analytic style. In this sense, a reflective "style" may make some of the same contributions to the learning of mathematics as field dependence-independence. The interaction between conceptual tempo and field articulation was considered worthy of investigation in this study.

Discussion of the major construct--locus of control

An early investigator of the construct of locus of control (internal-external) was Rotter; more recent investigators include Nowicki and Duke (1974). Locus of control refers to an individual's perception of the agency and the degree of control over one's environment. Control may be perceived as being internal or external. A person at the internal end of the continuum perceives outcomes to be a consequence of one's own actions. A person at the external pole perceives that outcomes are due to fate, luck, and other forces beyond personal control.

Although locus of control is referred to as a dimension of cognitive style by researchers (Starr, 1975; Rogerson, 1978; and Lewis & Feldhusen, 1977), this study contends locus of control might better be termed an individual difference variable (see model in Chapter 3). If cognitive style is defined as an information processing variable--as is done by most cognitive style researchers (i.e. Messick, 1976;

Witkin, et al., 1977; etc.), then locus of control would seem to be not a cognitive style variable, but subsumed under the broader term "individual difference variable". Viewed in this context, locus of control may be a construct that may influence or affect information processing--perceptual organization and/or conceptual categorization in cognition.

The construct locus of control was investigated for its intuitive relationship with field articulation and conceptual tempo. While minimal documentation was found in the research literature, "individuals with an articulated cognitive style (field independent) are likely to have internalized frames of reference to which they adhere as guides to self-definition and which they maintain as distinctly separate from external social referents. Those with a global style (field dependent) tend to rely more on external referents for self-definitions. On this basis we may expect that field-dependent students would be more likely to require externally defined goals and reinforcements than field-independent students who tend to have self-defined goals and reinforcements." (Witkin et al., 1977, p. 19)

Only a few studies were found relating locus of control to the learning of mathematics. Starr (1975) found mathematics ability correlated with internal locus of control for girls. Safran (1978) found no significant main effects of locus of control regarding achievement with fifth grade students. A slight relationship was reported between locus of control and mathematics grade expectancy by Rogerson (1978). Wagner (1973) in a study of nine and ten year olds, found field independents to be more internal, and more reflective

(conceptual tempo).

If the construct of locus of control is not influential in the learning of mathematics--an unverified assumption--the possibility remains that locus of control may be more influential in certain non-mathematics areas. Several studies, of which the Lewis and Feldhusen (1977) is typical, seems to suggest this. (Lewis and Feldhusen investigated locus of control, field articulation, and conceptual tempo in relation to achievement and attitudes in introductory psychology. Combining locus of control and reflectivity error scores yielded a multiple R of .48 with achievement. A significant canonical correlation was found between the set of cognitive style variables and the set of achievement and attitude scores.)

Discussion of the major construct--McKenney model dimensions

The cognitive style model developed by McKenney and colleagues at Harvard Business School has as a basic premise that "the individual selects and uses only part of the quantities of data imposed by the world as 'information'." (Nelson, 1974) The model's premise and the working definition of cognitive style in this study share similarities.

"Rather than being bi-polar, this model (McKenney) includes two dimensions affecting different aspects of information processing: information gathering and information evaluation. The information gathering aspect is the perceptual process by which the mind organizes and codes the wide variety of visual and auditory stimuli it encounters. Individuals may be either preceptive or receptive in this process. The information evaluation dimension relates to problem solving and reflects differences between a systematic and an intuitive

approach. Those who have a dominant style on this model are said to have information processing space which delineates the extent to which they tend to use each of the four modes (intuitive preceptive, intuitive receptive, systematic preceptive, or systematic receptive)." (Martens, 1976, p. 4)

While the model "seems" to relate to cognitive style as investigated in this study, the relevance of the model to the learning of mathematics has not been substantiated in the literature. At best, only five articles have been located that discuss the McKenney model--none of which relate directly to the learning of mathematics.

However, Project Priority, a two year cognitive style project designed by the Two-Year College Development Center (Martens, 1976), was a noteworthy study for two reasons: (1) the project was a large study at the two year college level (21 two year colleges participated), and (2) the study raised several critical questions concerning the relationship of the McKenney model dimensions to the established cognitive style dimensions of field articulation and conceptual tempo.

Because field articulation and conceptual tempo have been shown to relate to the learning of mathematics, and because the McKenney model "seems" related to the working definition of cognitive styles in this research, McKenney's dimensions will be investigated as they relate to the learning of mathematics at the two year college level.

Additional research findings that either reconfirm previously cited findings, or that offer additional implications for mathematics education are organized under the broad headings: cognitive style

characteristics, cognitive styles related to learning, teaching involving cognitive style research, and cognitive style useful in guidance and counseling.

Cognitive style characteristics

Black (1978) found over a period of five years, secondary school groups became more field independent and the rank order of subjects remained consistent. Frederick (1967), in a longitudinal study of sixth, eighth, and tenth graders, found that with age subjects became more analytical.

Cognitive style related to learning

In general, significant differences were found favoring pupils at grades 2, 3, and 6 with different cognitive styles. (Balik, 1976) A differential relation among IQ, mathematics achievement, and cognitive styles was also found by Gray (1976).

More specific dimensions of cognitive style investigated that relate to learning include: field dependence-independence, analytic-global (closely related to field dependence-independence), conceptual tempo, locus of control, structured-unstructured, symbolic-concrete, and focussing-scanning.

(a) field dependence-independence

Several researchers found significant relations between field dependence-independence and concept attainment strategies and cue preference (Kirschenbaum, 1968); efficiency and thoroughness in concept attainment were found to be related to field independence. (Dickstein, 1968)

Rosenfeld (1958) concluded that field independence is related to proficiency in mathematics in general. Studies by Farr (1968), Greenfield (1970), and Wagner (1973) show that a field independent cognitive style is positively related to nonverbal mathematics problem solving at different age levels. Significant differences favored field independents over field dependents on achievement in first year algebra. (Staskiewicz, 1977) Spotts & Mackler (1967) found field independents to have consistently higher scores in creativity than field dependent students. On tasks/tests requiring perceptual concept formation Elkind, et. al. (1963) determined that a field independent cognitive style is a definite asset.

(b) analytic-global

In regard to the analytic-global dimension, Broughton (1975) discovered that it has a positive linear relationship to classification ability to elementary children. High analytics performed better on concept identification than low analytics, and global subjects were less efficient on hypothesis testing behavior than analytics. (Davis, 1967) Nelson (1972) identified significant differences favoring analytic students over global students on learning geometric concepts.

On more broad criteria, analytic subjects had higher grade point averages than globals (Frederick, 1967); and Crisco (1975) determined a correspondence between analytic problem solving strategies and higher first semester grade point averages. (Prediction of academic performance increased with the addition of analytic-global cognitive style as a predictor.)

(c) conceptual tempo

Investigating conceptual tempo, Barstism and Ford (1977) suggested early school children learn to modify information processing tempo according to situational demands. Gray (1974) concluded that children who can switch styles across tasks performed better. McKinney (1974) discovered that among four, five, and six year olds, children with a reflective cognitive style were better problem solvers than impulsives. Reflective students tended to score higher than impulsives on the Metropolitan Achievement Mathematics Test in a study by Frierson (1975). In college females, Fein (1970) found significant differences favoring reflectives over impulsives on abstract reasoning performance. However, Genser (1977) claimed an impulsive approach to problem solving was to be preferred if the learning task had many dimensions.

(d) structured-unstructured; symbolic-concrete; focussing-scanning

In other studies: Tines (1973) concluded that students with focussing styles achieved significantly better than those with scanning styles. Pendleton (1975) found reflectives tend to use focussing strategies in problem solving while impulsives tend to use scanning strategies. Mitchell & Ault (1977) also showed a relationship between conceptual tempo and scanning strategies in problem solving. Edgell's work (1973) determined a positive correlation between analytic and reflective cognitive styles in learning mathematics concepts. Molina (1976) found the symbolic dimension of cognitive style related to success in mathematics at the college level.

Teaching involving cognitive style research

Hester and Tagatz (1971) produced several relevant findings. They illustrated a significant difference on concept attainment tasks produced by the interaction of cognitive styles with instructional strategies. Efficiency in concept attainment was dependent upon cognitive style. Further, attainment of concepts was more efficient when instruction was geared to the subject's learning style. Manipulation of cognitive styles can facilitate learning if cognitive styles are identified prior to training, and instruction on the concept attainment task is related to that cognitive style. Elliot (1976) also found partial support for matching learner traits and instructional treatments to produce learner gains.

Field independent students preferred discovery or lecture approaches while field dependents favored discussion or interaction. (Wu, 1967) Field independent/reflectives retained material better when taught deductively; field dependent/impulsives had better retention when taught inductively. (Koback, 1975) Black (1977) deemed students with low analytic cognitive styles better able to transfer when taught inductively.

Coop and Sigel (1971) imply cognitive styles related to teaching methods in the classroom are modifiable. Specifically, reflectiveness can be fostered according to Yando and Kagan (1968); Friedman (1974) modified the latency of impulsives with reflective instructions. Bien (1974) found perceptual and cognitive structuring techniques to increase problem solving success for field dependents in grade four.

A few studies involving cognitive style in aptitude treatment interaction (ATI) research reached different conclusions. Baldwin (1977) discovered an interaction of field dependence-independence with method of instruction. Threadgill (1976) saw no significant interaction between analytic/global cognitive style and method of instruction (didactic vs. discovery). Schneider (1976) discovered no significant interaction between field dependence-independence and treatment (rule then example vs. examples then rule). Field independents performed better when given minimum guidance and maximum opportunity for discovery, while field dependents performed better with maximum guidance and minimum opportunity for discovery. (McLeod and Adams, 1977) While ATI research has been relatively unsuccessful, suggestions for future improvements include need for longer treatments, more appropriate aptitude variables, better aptitude measures, and more refined uses of personality variables.

For tutorial purposes, Bowles and Boss (1974) suggested grouping students according to cognitive style. Bodine (1977) found groups composed of both field dependents and independents achieved better than groups composed solely of one type of style. Significant differences in grade point averages were found however when Campbell (1974) compared matched groups with mismatched groups.

Griffin (1974) used the cognitive style model of Hill to aid in individualizing instruction; and the same model was a factor in the success of a remedial mathematics program investigated by Berke (1976). Speer (1977) proposed a clinical model, incorporating the educational cognitive style of Hill, to diagnose mathematical deficiencies.

Cognitive style useful in guidance and counselling

Several studies have substantiated a differential cognitive style profile for successful vs. unsuccessful mathematics students. Beleutz (1975) used a collective educational cognitive style to differentiate between high successful and least successful mathematics students taking a computer programming course at both the sixth grade and the college level. Shuert (1970) obtained a unique profile from the Hill model of cognitive style of students who do well in mathematics.

The work of Ribleym (1977) seems to indicate separate educational cognitive styles exist for successful vs. unsuccessful general statistics students; within the collective styles, a profile existed to differentiate groups.

In Marten's study (1976), "new" college students with scores below thirty-three percent on admission tests tended to have the field dependence cognitive style. Oen (1973) found students tend to enroll in programs of study that match or complement their cognitive style. In a study of three categories of college majors, Deines (1974) found those in natural sciences were very field independent.

Chung (1966) suggests the use of cognitive style as predictors of college success, having discriminated among eight academic areas. Cognitive style was shown to be a significant predictor of arithmetic achievement as early as second grade by Stone (1976).

4) How does the present study relate to the existing research on cognitive styles; and finally, what contribution to mathematics education can this research on cognitive styles make?

A research base was compiled by searching recognized bibliographical references such as ERIC, Education Index, Dissertation Abstracts International, and the Journal for Research in Mathematics Education. Information and bibliographies from papers presented at the American Educational Research Association meetings were requested. In addition, citations (footnotes, bibliographical entries) in examined material were researched for references to cognitive styles related to mathematics education. The following purposes of investigation evolved from that search.

(a) to investigate the relationship of cognitive style to the learning of mathematics at the two year college level, and

(b) to examine the influence of cognitive style dimensions, not only in isolation, but in interaction with each other, as they relate to the learning of mathematics.

(a) Substantial findings exist relating cognitive styles to the learning and teaching of mathematics at various levels; and the implication is that cognitive styles have import at the college level. Yet, of over 250 references on cognitive style, relatively few studies using a college population were found. The relative sparsity of direct evidence hinders specific applicability of a cognitive style approach to the study of mathematics at the two year college setting.

Two specific studies held much promise for providing insight into the role of cognitive styles at the two year college level. Oen's investigation (1973) of the interaction of cognitive styles and types of learning experiences in vocational technical education was an attempt to identify and use knowledge of learning styles needed in gaining

technical skills and knowledge. However, the questionable selection of cognitive style dimensions and the research techniques used severely limited both the validity and the generalizability.

On a much larger scale, Project Priority (Martens (Ed.), 1976), supervised by the Two Year College Student Development Center in New York, attempted to pose and answer several critical questions. The relative lack of valid conclusions is in part reflective of design and sampling problems, and inconsistent analyses. The results are acknowledged as tentative with the value inherent not in what was shown, but in the implications suggested.

In this framework, the intent is to extend present research findings to the two year college level, to validate tentative findings from existing studies, and to test several raised questions. With the relative newness of cognitive style research, coupled with the surfeit of existing cognitive style dimensions, the contention exists--at present--that more is to be gained by broader unifying research as opposed to isolated investigations of one or two dimensions to an overly specific aspect of learning mathematics. Therefore, to explore trends and to provide a research framework for ensuing investigations, the relationship of several selected cognitive style dimensions to the global constructs of mathematics achievement, aptitude, and attitudes will be studied.

(b) Again, of the many research studies investigated, relatively few examined the effects of more than one cognitive style dimension in relation to the learning of mathematics. Yet, if significant conclusions were reached, almost total credit was given to the single

dimension under investigation. Interpretations such as these seem to run counter to the view of learning as possessing a multi-faceted nature. With the plethora of multivariate techniques available, greater considerations can be given tc possible interactions, and assessment of unique contributions to several individual cognitive style dimensions.

Noteworthy studies include those by Nelson (effects of analytic-global and reflective-impulsive cognitive styles on the acquisition of geometric concepts, 1972) and Koback (interactive effects of field dependence-independence and conceptual tempo on learning mathematics at the fifth grade level, 1975). Edgell (1973) and Pendleton (1975) each investigated the relationship of the cognitive style dimensions analytic-global and reflective-impulsive to focussing vs. scanning strategies on mathematical concepts. Martens (1976) investigated field dependence-independence and the McKinney model dimensions of cognitive style.

An investigation of the research literature revealed those dimensions of cognitive style that either have import for the learning of mathematics and/or those which need investigation. "Any one of the styles (dimensions) might have implications for research into mathematics learning." (Fennema & Behr, in press) As the review of the literature indicated, many dimensions have been researched and do have implications for learning/teaching mathematics.

The selection of the dimensions for investigation was accomplished in the following manner. Field dependence-independence and conceptual tempo "have the most apparent implications for the learning of

mathematics" (Fennema & Behr, in press); in addition, each of these dimensions has accumulated a rather broad base of research. (i.e. In Field Dependence-Independence and Psychological Differentiation: A Bibliography Through 1972 with Index, (Witkin et al., 1973), nearly 1600 reports concerning field dependence-independence were listed; more recent reviews can also be found--Witkin, Cox, & Friedman (1976)).

The McKenney model has been chosen because of its origins in the works of Bruner and Witkin; more important in the selection, however, was the fact that this is one of the few dimensions that has been investigated at the post secondary level (Project Priority, Two Year College Development Center in New York). The research base on the McKenney model is scant at best and the dimensions would benefit from a thorough analysis, especially if these dimensions are to be used in conjunction with research in learning mathematics. Questions raised include: (a) Are each of the two dimensions bi-polar? (b) Are indeed the dimensions orthogonal to each other? and (c) Do these dimensions contribute additional insight into the learning of mathematics over and beyond the contribution of the established dimensions field articulation and conceptual tempo?

Locus of control has been chosen, also, for the seemingly "intuitive" relationship with field articulation. The questionable inclusion of locus of control as a cognitive style variable--rather than as a broader individual difference variable--should be addressed. Other questions raised include: (a) Is locus of control related to the learning of mathematics at the two year college level? (b) Does locus of control contribute additional insight into the learning of

mathematics over and beyond the contribution of the established dimensions field articulation and conceptual tempo? and (c) Is the Adult Nowicki-Strickland Locus of Control scale indeed a reliable and valid measure of the locus of control construct?

In regard to inclusion of the McKenney model and locus of control in this investigation, the following remarks from Fennema & Behr (1980) seem apropos: "in the area of many cognitive styles, formulation of hypotheses for mathematics learning is largely nonexistent...whether or not the effect of various cognitive styles on mathematics learning emerges as an important research area will depend upon more validation of cognitive style as a construct and upon the development and listing of creative hypotheses by researchers in mathematics education." (in press)

The intent is to examine the relationship of each dimension, field articulation, conceptual tempo, McKenney model, and locus of control, as well as possible interrelationships, to determine the relative independence of each and/or the unique contribution of each dimension to the learning of mathematics.

A sufficient number of studies (Black, 1977; Erginell, 1970; Fein, 1970; Frehner, 1973; Gordon, 1977; Satterly, 1976; and Fennema & Behr, 1980) have raised pertinent questions and discussion on the possible confounding and/or interactive effects of intelligence to cognitive style dimensions. Therefore, rather than examining only the interrelationships and unique contributions of the cognitive style dimensions, this study will investigate the possible intervention of intelligence, or general reasoning.

CHAPTER III

The research design and procedures chapter begins with a research model relating the cognitive style dimensions to the mathematics criterion variables. The presentation of the methodology and procedures, then, has been subdivided into the following eight major components: selection of cognitive style dimensions, pilot study, questions for investigation, instrumentation, population and sample, data collection, summary of hypotheses, and analysis of data.

Research Model

The body of cognitive style literature abounds with a multitude of dimensions, as well as numerous conceptualizations of the construct of cognitive style. "Despite the elements of common interest in the study of cognitive style, various investigators disagree on the details of the approach of cognitive style and the use of measuring instruments. This had resulted in a body of literature from which it is difficult to extract general principles." (Goldstein & Blackman, 1978, p. 4) Kagan and Henker (1966), among others, have pointed out the need for systematization at all levels of theory and research. In the context of these remarks, Figure 6 attempts to depict a research model. The cognitive style dimensions investigated--pictured as a subset of learning style variables and individual difference variables--are related, in the figure, to both intelligence and the mathematics criterion variables.

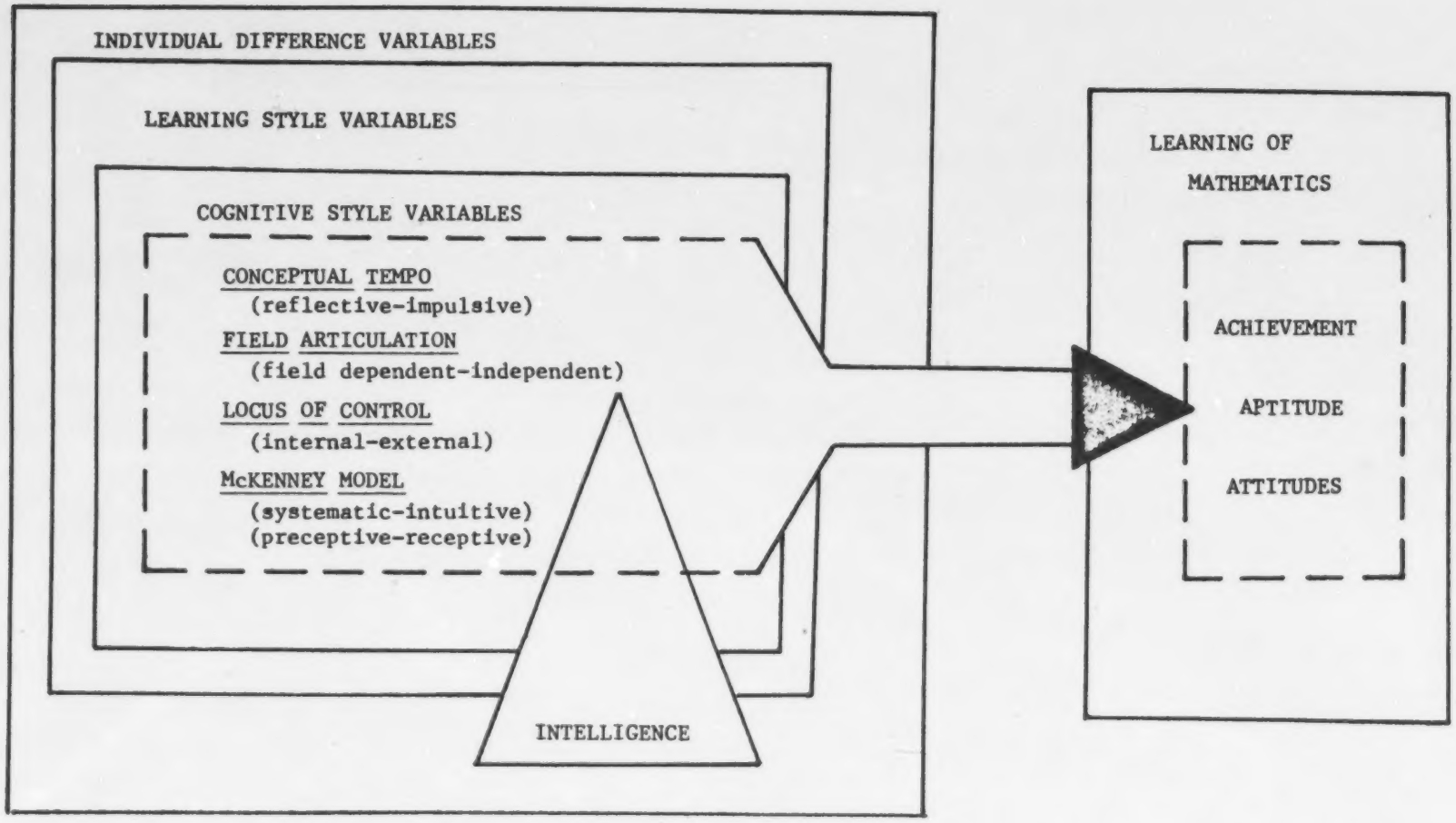


Figure 6. Research model relating the cognitive style dimensions and intelligence to the mathematics criterion variables

Selection of Cognitive Style Dimensions

The review of the research literature revealed thosed selected dimensions of cognitive style shown to have import for the learning of mathematics and those which need investigation. By conducting a pilot study, further scrutiny was made of those dimensions and their assessment instruments. These specific dimensions, together with their respective constructs, principal investigators, and assessment instruments are summarized in Table 2. (The assessment instruments used in the major study are underlined.)

Table 2

Cognitive Style Dimensions, Constructs, and Assessment Instruments

Cognitive style dimension	Construct	Principal Investigators	Assessment Instruments
field articulation	field dependence-field independence	Witkin (1977)	Embedded Figures Test, Group Embedded Figures Test, Hidden Figures Test, Rod-and-Frame Test
conceptual tempo	reflective-impulsive	Kagan (1964)	Conceptual Styles Test, Design Recall Test, Matching Familiar Figures Test
McKenney model		McKenney (1974)	
(a) information gathering	preceptive-receptive	Nelson (1974)	Symbols Test, Identical Pictures, Following Directions, Scrambled Words
(b) information evaluation	systematic-intuitive		
locus of control	internal-external	Nowicki (1974) Lewis & Feldhusen (1976)	Adult Nowicki-Strickland Internal External Control Scale, Rotter Internal External Scale

Pilot Study

A pilot study was conducted to accomplish the following objectives:

(a) to delimit the scope of the area of investigation regarding cognitive style dimensions

(b) to ascertain the feasibility of successfully discovering relationships of the cognitive style dimensions to achievement, aptitude, and attitudes

(c) to judge the desirability of the assessment instruments for the constructs of interest

(d) to obtain measures on the psychometric properties of each assessment instrument for the two year college population

(e) to gauge the motivational level and cooperative effort of the two year college student.

Twenty-seven students were selected, nine from each of three different areas of study: general business management, medical laboratory, and electronic engineering. These three groups best represented the different types of mathematics preparation given at the college. If relations among the cognitive style dimensions were evident, trends would be noticed among these three groups.

To obtain the pilot sample, twenty-eight students, randomly selected, were contacted. The participating sample was 96% of the invited sample. During five weeks, each subject completed eleven assessment instruments; each was individually administered by the experimenter. To avoid fatigue or practice effect, no more than 40 minutes of testing was conducted at one setting; total time per student

was approximately two hours.

Students were told in return for their cooperation, a better understanding of their "individual learning style" would be realized. Although a subjective judgement, motivational level and cooperative effort were considered excellent by the experimenter. All students upon completion, received a cognitive style profile and a four-page descriptive summary of their results.

From this initial exploratory study, a list of twenty questions of interest was narrowed to three for further investigation. Although not all were statistically significant ($p < .05$), trends and relations regarding the cognitive style dimensions were found. The construct validity and reliability of the cognitive style instruments were considered appropriate for further use. Because no standardized achievement test results, such as ACT scores, were available for all students, and because the analysis of the pilot data could have benefited from a more refined measure of achievement rather than grade point average, the decision was made to use the Columbus Technical Institute Mathematics Placement Tests to assess achievement. Of the two possible measures of aptitude, psychometric properties favored the Mathematics Aptitude Test to assess that construct.

A limitation of the pilot study which suggested guidelines for future research was the size of the sample. The small n (27) severely limited valid use of regression analysis and the multivariate techniques of multivariate analysis of variance and discriminant analysis. Findings of the pilot study should be interpreted in accordance with this fact. Specific findings are reported in Appendix A.

Questions for Investigation

From reflection upon the research literature and the outcomes of the pilot study the purpose evolved to explore and examine the correlative, predictive, and differential nature of selected cognitive style dimensions as they relate to the learning of mathematics by two year college students. More specifically, the relationship of the profile of the cognitive style dimensions: conceptual tempo, field articulation, locus of control, preceptive-receptive, and intuitive-systematic, was analyzed with regard to mathematics achievement, aptitude for mathematics, and attitudes toward mathematics.

Investigative efforts focussed on providing insight to three major questions:

1) Is there a significant correlational relationship between subsets of scores from students' cognitive style dimensions and subsets of scores from their achievement in mathematics, aptitude for mathematics, and attitudes toward mathematics?

2) Which cognitive style dimensions, separately or combined, are significant predictors of (a) achievement in mathematics, (b) aptitude for mathematics, and (c) attitudes toward mathematics?

3) Are cognitive style dimensions differentially exhibited in students in different mathematics sequences of study; and, if so, which cognitive style dimensions, separately or combined, significantly discriminate between students in the different mathematics sequences?

Instrumentation

To provide information on the cognitive style dimensions, as well as provide measures of intelligence, mathematics achievement, aptitude, and attitude, the following eleven assessment instruments were used.

Assessment Instrument	(Acronym)	Construct Measured	Time Restriction
Adult Nowicki-Strickland Internal External Control Scale	(ANSIE)	Locus of control	none
Following Directions	(FDS)	Systematic	14 min.
Group Embedded Figures Test	(GEFT)	Field articulation	12 min.
Identical Pictures	(IPR)	Receptive	3 min.
Matching Familiar Figures Test	(MFFT)	Conceptual tempo	individually timed
Scrambled Words	(SWI)	Intuitive	10 min.
Symbols Test	(STP)	Preceptive	10 min.
Advanced Progressive Matrices--II	(APM)	Intelligence	30 min.
Columbus Technical Institute Mathematics Placement Tests	(CTIACH)	Mathematics achievement	none
Mathematics Aptitude Test	(MAT)	Aptitude for mathematics	20 min.
Revised Math Attitude Scale	(RMAS)	Attitude toward mathematics	none

Based on the findings of both the pilot study and prior research, selection of each particular instrument was appropriately substantiated. Consideration was given to the following psychometric properties: reliability, construct validity, content validity, and criterion-referenced validity. A brief description of each instrument together

with the aforementioned specific characteristics of each is reported.

The Adult Nowicki-Strickland Internal External Control Scale (ANSIE) consists of 40 items answered yes or no. A person's score is the sum of the weighted alternatives with yes = 1 and no = 0. A larger sum would indicate more external control. A sample item from ANSIE follows in Figure 7:

Answer with either: an N if you feel the answer is NO
or: a Y if you feel the answer is YES

___ Do you feel that when you do something wrong there's very little you can do to make it right?

Figure 7. Sample test item from ANSIE

Since the instrument is relatively new, psychometric characteristics tend to be sparse--but those reported include: (a) internal consistency - split half reliabilities in the .60s for college samples (Nowicki & Duke, 1974); KR 20 of .69 for male sample (Anderson, 1976); (b) test-retest reliability - for college students, Nowicki & Duke (1974) reported .83 over a seven week period; Chandler (1976) reported .65 over a six week period; (c) construct validity - significant and consistent correlates ($r = .68$, $df = 47$, $p < .01$; $r = .48$, $df = 37$, $p < .01$) with the Rotter scale, a historically significant measure of locus of control.

Although the historical significance of the Rotter scale cannot be denied, the scale has been criticized for the following reasons: Rotter I-E scores (a) have shown a significant relation to social desirability, (b) confound personal and social casusation, and (c) are inappropriate for non college populations because of the scale's forced choice format and difficult reading level. ANSIE was constructed to circumvent these criticisms.

Reliabilites reported for the pilot study (n = 27) and for the major study (n = 180) are respectively 0.37 and 0.64.

The Group Embedded Figures Test (GEFT) is the group adaptation of the Embedded Figures Test. The test consists of attempting to locate one of eight simple figures within a complex figure. After a two minute practice session on seven items, subjects have five minutes for each of two parts--each part containing nine complex figures. The score on GEFT is how many simple figures are correctly disembedded from the 18 complex figures in the allotted time. High scores are associated with field independence while low scores are associated with field dependence.

A sample item from GEFT follows in Figure 8.

Find simple form, labelled "A", within the more complex figure and trace it with pencil over the lines of the complex figure.

The simple form is the same size, in the same proportions, and faces in the same direction.

Simple form "A" Complex form

Figure 8. Sample test item from GEFT

Results of many studies (Dreyer, Nebelkopf, and Dreyer (1969); Adevai and McGough (1968); Witkin, Oltman, and Raskin (1971) indicate that the major measures of field dependence have satisfactory reliabilities. Witkin, et al. (1962) reported that in the results of their own research and others, the reliabilities were satisfactorily high, clustering in the high .80s to low .90s. Concerning the validity of the test, Gough (1965) in a review of EFT and Witkin's research efforts remarks that "one of the most attractive features of this test is its fine anchoring in a systematic context of theory and empirical evidence. The test's diagnostic implications are seen related to (a) field independence, (b) cognitive clarity, (c) an analytic versus global perceptual mode, and (d) a general disposition to articulate and structure experience."

Reliabilities for the pilot study (n=27) and major study (n=180) were respectively .85 and .83.

Following Directions (FDS), Identical Pictures (IPR), Scrambled Words (SWI), and the Symbols Test (STP) are marker tests from the Kit of Factor-Referenced Cognitive Tests, (Educational Testing Service, 1976). Prior use was made of these instruments in a "similar" capacity by "Project Priority" at the Two Year College Development Center, State University of New York. The thirteen projects, with as many participating campuses, ranged from 17 to 459 students and faculty. However, the big limitation of these tests is lack of reported psychometric data--especially regarding validity.

The inclusion of these tests in the present study of two year college students is primarily to substantiate and/or replicate findings

from the study consisting of two year colleges in New York.

Hence, for each of these four tests only four items are reported: (1) a brief description of the test, (2) the construct the test purported to measure in "Project Priority" (the origin of these constructs is from the information processing model by McKenney (1972, 1974), (3) the factor the test purports to measure according to the Educational Testing Service, and (4) the reliabilities from both the pilot study and the present major study of this investigation.

FDS is two part 20 item multiple choice test. By following rules or certain directions for each question, a correct letter is to be selected from a 5 by 5 matrix of letters. A different matrix is given for each part of the test. A person's score is the number correct minus one fourth the number incorrect. A high score identifies systematic individuals.

A sample item appears in Figure 9.

Look at this example:

	Column				
	1	2	3	4	5
Row 1	A	B	C	D	E
Row 2	E	A	B	C	D
Row 3	D	E	A	B	C
Row 4	C	D	E	A	B
Row 5	B	C	D	E	A

Which is the only letter that appears directly above the letter A?

Circle your answer: A B C D E

Figure 9. Sample test item from FDS

In McKenney's model the test is to measure the construct "systematic". "Systematic individuals tend to approach a problem by devising a method or plan with specific, sequential steps to solutions." (Nelson, 1974, p. 6)

The factor the test measures according to ETS is "integrative processes-ability to keep in mind simultaneously or to continue several conditions, premises, or rules in order to produce a correct response". (Ekstrom et al., 1976, p. 87) Note should be made of the fact that loadings on memory are minimized since in this test rules are readily available for reference.

Reliability measures reported for the pilot study and major study are .75 and .73 respectively.

IPR is a two part test with each part containing 48 items. A figure is given with 5 similar figures adjacent; the subject is to scan the alternatives and select the matching symbol. Score is the total number correct. A high score identifies receptive individuals.

A few sample items are shown in Figure 10.

How fast can you match a given object? Blacken the space below the object that matches the object on the left.

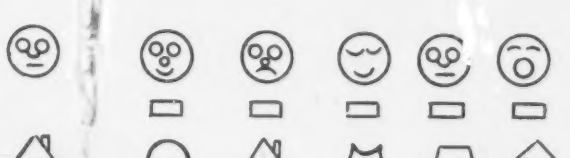


Figure 10. Sample test items from IPR

In McKenney's model the test is to measure the construct "receptive". Receptive individuals "are more sensitive to the stimulus itself. They focus on detail rather than relationships and try to derive the attribute of the stimuli from direct examination instead of fitting it to their precepts." (Nelson, 1974, p. 4)

ETS's purpose for the test is to measure "perceptual speed - speed in comparing figures or symbols, scanning to find figures or symbols". (Ekstrom, et al., 1976, p. 123) Acknowledgement is made that the factor may be the centroid of several subfactors such as form discrimination and symbol discrimination which can be separated, but for research purposes a single concept is used.

Reliability measures reported for the pilot study and major study are .88 and .91 respectively. However, being a speed test, these reliability estimates may be inflated.

SWI is a two part test with each part containing 25 scrambled words. Within 5 minutes for each part, the subject is to unscramble as many words as possible. Score is the total number of words correctly unscrambled. A high score identifies intuitive individuals.

In McKenney's model the test is to measure the construct "intuitive". "Intuitive individuals more often consider using trial-and-error, defining or redefining the problem, moving back to a solution and so on." (Nelson, 1974, p. 4)

A few practice items are given in Figure 11.

Print or write clearly the word that can be made by unscrambling the letters.

ievg _____

veah _____

birc _____

Figure 11. Sample test items from SWI

ETS claims the test measures the factor "verbal closure - the ability to solve problems requiring the identification of visually presented words when some of the letters are scrambled". (Ekstrom et al., 1976, p. 61)

Reliabilities reported for the pilot and major study are .89 and .90 respectively. Being a speed test, SWI probably has inflated reliabilities.

STP is a two part test, each part having a five minute time restriction. On each part, five words are given as stimuli; the subject is to represent that word with different symbols. For each word a maximum of symbols is allowed. The score is the total number of different symbols drawn. A high score identifies preceptive individuals.

A practice item is pictured in Figure 12.

In the sample the word is food. A sketch has been made to represent a fork and spoon. Draw other symbols that could represent food.

FOOD:

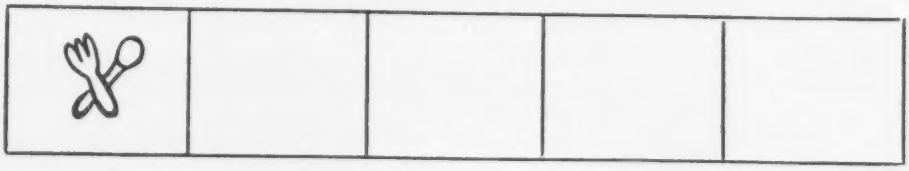


Figure 12. Sample test item from STP

In McKenney's model the test is to measure the construct "preceptive". Preceptive individuals "tend to use concepts and categories to code data. They look for relationships between stimuli so that they can efficiently catalogue information." (Nelson, 1974, p. 3)

ETS uses the test to measure the factor "figural fluency - ability to draw quickly a number of examples, elaborations, or restructurings based on a given visual or descriptive stimulus". (Ekstrom et al., 1976, p. 61)

Reliabilities for the pilot and major study were .74 and .88 respectively.

MFFT The Matching Familiar Figures Test (Kagan et al., 1964) is used to assess the dimension reflection-impulsivity. After two practice items, the subject is presented with twelve test pictures. For each test picture, the subject is to select from 8 almost identical alternatives, the one that exactly matches the stimulus picture. The selection process continues until the correct match is located. For the 12 items two scores are obtained: (1) mean latency of initial response, and (2) mean error score.

A practice item, reduced 75%, is presented in Figure 13.

Criterion referenced validity was assessed by cross-referencing the results of six different studies--reported by Kagan et al. (1964)--utilizing the Matching Familiar Figures Test, the Conceptual Styles Test, and the Design Recall Test, DRT.

There exists a low positive correlation between DRT and IQ scores. DRT had geometric designs and also included an immediate memory

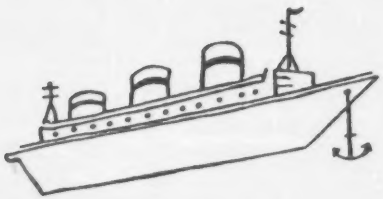


Figure 13. A practice item from the Matching Familiar Figures Test (stimulus picture)

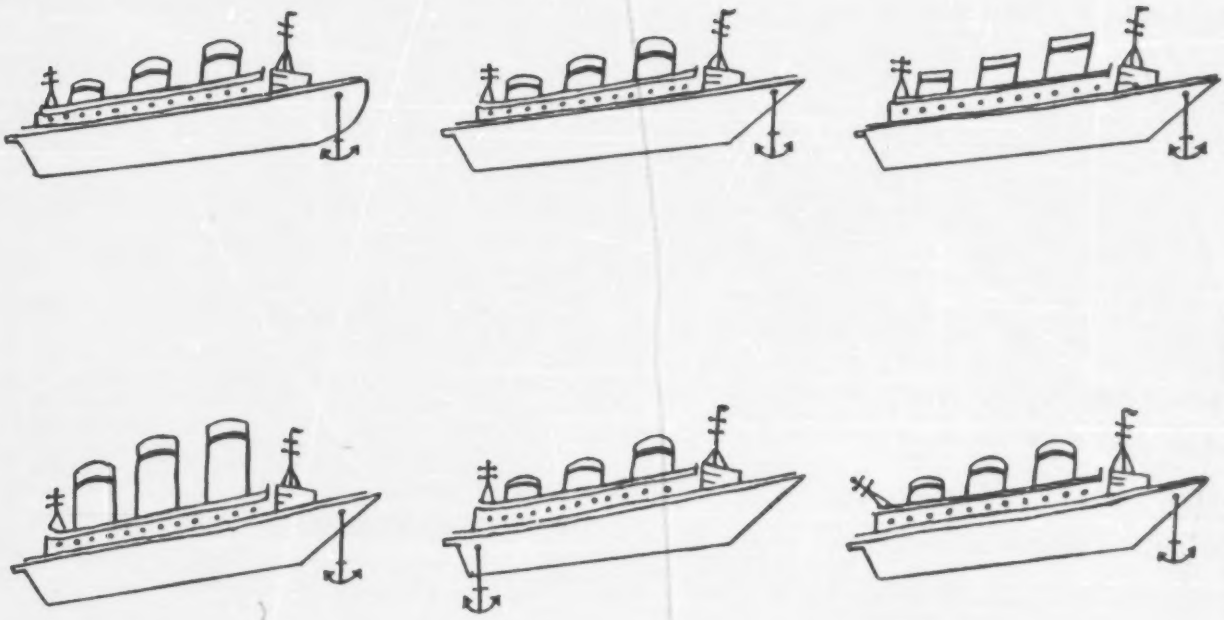


Figure 13. A practice item from the Matching Familiar Figures Test (continued)

component. By using familiar objects rather than geometric figures, MFFT attempted to lower the relation with IQ; in addition, MFFT did not require a memory component. MFFT is minimally related to verbal skills.

For the two scores obtained from MFFT, there exists a high negative relation between MFFT mean latency of initial response and mean error score (e.g. $r \leq -0.500$). One measure of internal consistency for the error scores was a split half reliability of .72.

The Advanced Progressive Matrices (APM), Sets I & II, are non-verbal tests of intellectual efficiency. Being non-verbal the tests have the advantage that clarity of thought processes are assessed independent of educational attainment. For the amount of time spent giving the test, the information obtained is more exact and valuable over performance tests. With a time limit they are used to assess a person's total capacity for observation and clear thinking. Set I has 12 problems; set II has 36.

A practice item is presented in Figure 14.

As reported in the Psychological Corporation's Manual, test-retest reliabilities ranged from .76 for 10½ year students to .91 for adult students. Validity was checked by comparing APM set II to the Standard Progressive Matrices. With scores between 20 and 30 there exists approximately 1 to 1 agreement with the scores from SPM. For scores greater than 30, APM set II appeared to provide an increasingly accurate differential estimate.

In the pilot study, APM set I was used as the measure of intelligence. The brevity of the test, with a low reliability measure (.46), prompted use of a portion of the 36 item APM set II instrument.

DIRECTIONS:

The upper figure is a pattern with a piece cut out of it. Each of the eight figures below is the right shape to fill the space. Pick the one which, if it was put back, would complete the pattern properly both across and down.

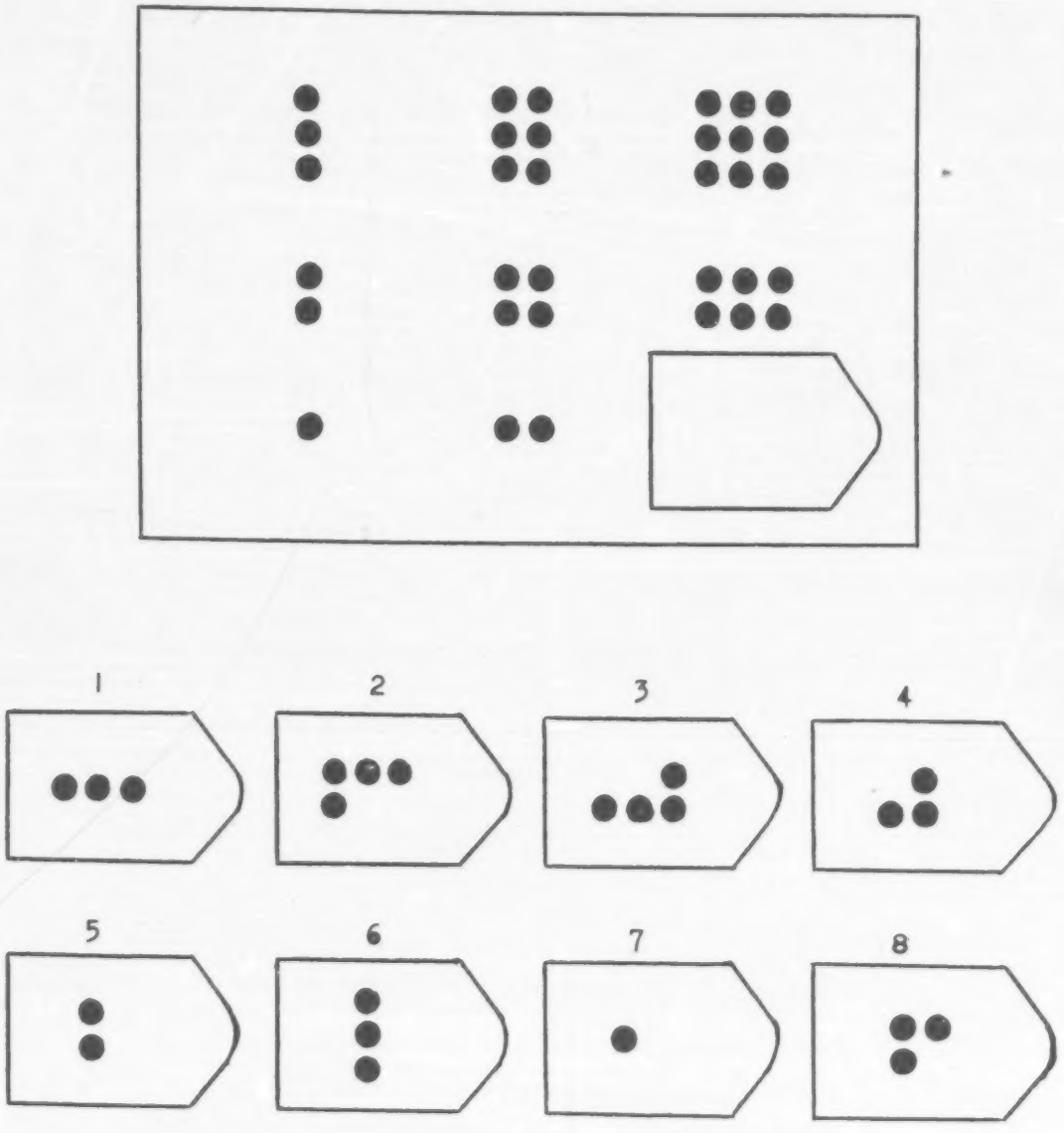


Figure 14. Practice item from Advanced Progressive Matrices II

Within a time limit of 30 minutes, subjects were to do as many of the first 30 items as possible. Reliability reported for the major study was .74. The person's score was the number correct out of the 30 items attempted.

The Columbus Technical Institute Mathematics Placement Tests (CTIACH). In the pilot study college mathematics grade point average was used as the measure of achievement. Desiring a more thorough and precise measure of achievement, many possible achievement tests were surveyed. Because of the wide variety in requirements and prior mathematical backgrounds, great difficulty was encountered in procuring one test appropriate for all subgroups. The decision was made to use the college's mathematics placement tests to measure achievement.

Several sample problems from these tests are given in Figure 15.

1. Solve the proportion for X: $5/30 = 3/X$
2. 360 is what percent of 480 ?
3. Simplify: $\dfrac{M^2 + 3M - 28}{M^2 + M - 20}$

Figure 15. Sample problems from Columbus Technical Institute Mathematics Placement tests

Face validity was judged more than satisfactory by members of the college's mathematics faculty. When given as multiple choice tests, the following statistics were reported. (See Table 3.)

Because different subtests were used, each measuring mathematics achievement, an attempt was made to standardize the statistics. Each achievement raw score (number correct) was recorded as a percent correct (ACHRAW); these were then changed to standard scores with a mean of 50

Table 3

Psychometric Data for Achievement Tests

Subtest for:	ACT	BDP	ELE	GBM	MED	NUR
number of items	30	40	35	30	40	50
n	74	74	74	85	109	76
reliability KR 20	.82	.85	.85	.83	.89	.98
KR 21	.79	.81	.84	.81	.87	.96
mean item discrimination	.38	.39	.36	.41	.38	.85
mean item difficulty	.58	.72	.68	.64	.75	.46

The reliabilities for the tests in the major study (not used as multiple choice tests) are reported as follows:

.77	.87	.76	.69	.75	.91

and a standard deviation of 10 (ACHSSC).

MAT The Educational Testing Service used the Mathematics Aptitude Test, along with two other tests to measure the factor "general reasoning--ability to select and organize relevant information for the solution of a problem". (Ekstrom et al., 1976, p. 133) Two of the three tests, the Mathematics Aptitude Test and the Necessary Arithmetic Operations Test were used in the pilot study. Because the MAT had a higher internal consistency measure of .74 (n = 27), and the face validity was judged very acceptable by members of the college's mathematics faculty, the MAT was used in the major study to assess aptitude for mathematics.

MAT is a two part, 30 questions test, with multiple choice format. A person's score is the total number correct minus ¼ the number incorrect.

Reliability for MAT in the major study was .68.

An example problem is given in Figure 16.

How many candy mints can you buy for 50 cents at the rate of 2 for 5 cents?

A - 10
B - 20
C - 25
D - 100
E - 125

Figure 16. Sample problem from MAT

The Revised Math Attitude Scale (RMAS) is a 20-item scale developed by Aiken and Dreger (1961). The Likert scale response alternatives are weighted from 0 to 4. A student's score is the sum of the weighted alternatives with a high score reflecting a positive attitude toward mathematics. The authors report test-retest a reliability coefficient of .94 and also claim satisfactory content validity.

Hoyt reliability measures for the pilot study and major study were .74 and .62 respectively.

A sample item is shown in Figure 17.

Circle the letter(s) which best indicates how closely you agree or disagree with the feeling expressed in each statement as it concerns you.

SD = strongly disagree, D = disagree, U = undecided, A = agree, and SA = strongly agree

I am happier in a math class than in any other class.	SD	D	U	A	SA

Figure 17. Sample item from RMAS

Population

The population consisted of two-year college students enrolled at Columbus Technical Institute. Part of Ohio's two-year campus system, the technical colleges serve their community with two-year technical-degree programs. Because of the rapidly escalating interest in technical education, the technical colleges have has one of the fastest growing enrollments in the state. The main thrust of technical education is to train people for specific semiprofessional jobs. But strong emphasis is also placed on general education to assure that students gain a broad educational base. General education courses, such as mathematics, make up approximately 50% of the curriculum in two year associate degree technical programs.

There are sixteen technical colleges in Ohio; Columbus Technical Institute is the largest. Some of the descriptive statistics concerning Columbus Technical Institute are provided, based on 1979 data. The actual head count was 5474 students with the FTE count at 3910. Of the students enrolled, 98% were Ohio residents, representing 78 out of 88 Ohio counties. 82% of the students were white, non-Hispanic, while 16% were black. The average age was 25 while the median age was 23. The male to female ratio was 47 to 53. 30% of the students were married. Of the total number of students, 54% were full time students, each carrying an average of 4.1 classes and enrolled for 14.5 credit hours.

Sample

Subjects in the major portion of the study were 180 two-year college students representing six, out of twenty-seven, different technologies.

The six technologies were selected because each required mathematics courses of a different nature (e.g., different conceptual levels, difficulty levels, breadth of coverage, essential content for the technology, etc.). The six different representations of mathematics sequences, or technologies, are referred to by the following acronyms: accounting (ACT), business data processing (BDP), electronics engineering (ELE), general business management (GBM), medical laboratory (MED), and nursing (NUR).

For each technology, the representative counselor randomly selected a list of forty to fifty names by a stratified constant sampling technique. To assist in assuring generalizability of findings, and to adequately represent the student enrollment, a ratio of 3 to 1 was approximated in selecting first year and second year students.

Students were individually contacted by the investigator either by phone or in person until 32 participants were selected from each technology. By participating and completing all assessment instruments, subjects understood they would become more familiar with their individual "learning style", as well as learn more about the composite "learning style" of their chosen technology, compared to other technologies. Since the desired number of final subjects was to be a minimum of 30 per technology, additional subjects were selected to guard against subject mortality and/or to eliminate possible "outlier" scores in the final data analysis.

The composite participating sample represented 83.7% of the invited sample. The two main reasons for non-participation were either (1) students were switching technologies or schools, or (2) students with

work schedules and study schedules did not have adequate time for the "learning style project". A more detailed breakdown, by technology, is presented in summary form in Table 4.

Table 4

Invited Sample Compared to Participating Sample

	Technology						Total
	ACT	BDP	ELE	GBM	MED	NUR	
Number in invited sample	38	37	37	38	34	37	221
Number in participating sample	30	32	31	30	31	31	185
Participating as a percent of invited	79%	87%	84%	79%	91%	84%	83.7%
Number used in study	30	30	30	30	30	30	180

Some descriptive statistics on the research sample, by subgroup and as a composite, are also listed in summary form in Table 5.

Table 5

Descriptive Statistics on Participating Sample

Variable	ACT	BDP	ELE	GBM	MED	NUR	Total
Age	25.1	25.8	22.6	23.0	22.1	26.6	24.2
Female to male ratio	7:3	1:1	1:9	3:5	5:1	9:1	6:4
Grade point average	2.95	3.32	2.94	2.59	2.92	3.09	2.95

Means and standard deviations, together with histograms for each subgroup for each variable under investigation, are reported in Appendices B and C respectively.

Data Collection

All data were collected during spring quarter, 1979. At the first testing session, students were again given a brief overview of the "learning style project". (A copy of a written introduction to the project is included in Appendix D.) In addition, the necessary time commitment and involvement of the participants were reiterated. Again, provisions or complete anonymity of participation were guaranteed.

During eleven weeks, each subject completed eleven assessment instruments. Three sessions, two for group testing and the remaining session for individual testing, were used to collect the data. The three assessment instruments with no time restriction (ANSIE, CTIACH, and RMAS) were distributed at the first session and were to be completed outside the testing sessions. Although this procedure is questionable, the consideration of possibly jeopardizing validity was overweighed by the importance of including these three measures in the study without increasing the excessive scheduled time commitment on the part of the student.

All other assessment instruments, except the MFFT were administered as group tests to groups of 10 or more at a time. For each group the order of the tests was randomly decided. The MFFT was individually administered by the researcher or one of five research assistants. Again, as in the pilot study, to avoid fatigue or practice effect, no

more than 50 minutes of testing was conducted at one setting. The total testing time per student was approximately 2½ hours. All phases of the testing program were supervised by both the Department of Admissions and Testing, and the researcher.

Additional information collected on each subject included age (AGE), sex (SEX), overall college grade point average (CTIGPA), college mathematics grade point average (CTIMGP), and high school mathematics product index (HSMPI)--number of mathematics courses x grade point average. (All research variables and acronyms are listed in Appendix E.)

Summary of Hypotheses

With the research intent being to investigate the correlative, predictive, and differential nature of selected cognitive style dimensions--as they related to the learning of mathematics--the specific research hypotheses are listed under these three areas.

Correlational nature

Hypothesis 1: None of the following variables will exhibit first order correlations with any of the others in a significant manner.

The student's position on each cognitive style dimension:

(a) field articulation as measured by the Group Embedded Figures Test
(b) conceptual tempo as measured by the Matching Familiar Figures Test
(c) locus of control as measured by the Adult Nowicki-Strickland Internal External Scale
(d) preceptive-receptive as measured by the Symbols Test and Identical Pictures
(e) intuitive-systematic as measured by Scrambled Words and Following Directions

and the student's:

(f) high school mathematics product index
(g) college mathematics grade point average
(h) mathematics achievement as measured by Columbus Technical Inatitute's Mathematics Placement Tests
(i) aptitude for mathematics as measured by the Mathematics Aptitude Test
(j) attitude toward mathematics as measured by the Revised Math Attitude Scale
(k) measure of intelligence as determined by Advanced Progressive Matrices--set II

Hypothesis 2: The subset of scores from the cognitive style dimensions will not exhibit a significant canonical correlation with the subset of scores from mathematics achievement, aptitude, and attitudes.

Predictive nature and additional correlational analyses

Hypothesis 3: None of the cognitive style dimensions will make a significant contribution to the multiple correlation with:

(a) mathematics achievement
(b) aptitude for mathematics
(c) attitudes toward mathematics

Hypothesis 4: Including the measure of intelligence, in addition to the cognitive style dimensions, will not significantly change the multiple correlations in Hypothesis 3.

Differential nature

Hypothesis 5: For each of the cognitive style dimensions:

(a) field articulation
(b) conceptual tempo
(c) locus of control
(d) preceptive-receptive
(e) intuitive-systematic

there will be no significant difference between groups of students in the different mathematics sequences.

Hypothesis 6: For each of the cognitive style dimensions:

(a) field articulation
(b) conceptual tempo
(c) locus of control
(d) preceptive-receptive
(e) intuitive-systematic

there will be no significant difference between groups of students in the different mathematics sequences, provided intelligence is partialled out.

Hypothesis 7: The profile of cognitive style dimensions will not significantly discriminate between students in different mathematics sequences of study.

Analysis of Data

A brief overview of the analyses is presented by hypothesis.

A correlational matrix was computed to examine the first order correlations for the variables in Hypothesis 1.

Canonical correlations were obtained for the subset of scores from the cognitive style dimensions with the subset of scores from mathematics achievement, aptitude, and attitudes. This latter analysis is depicted diagramatically in Figure 18.

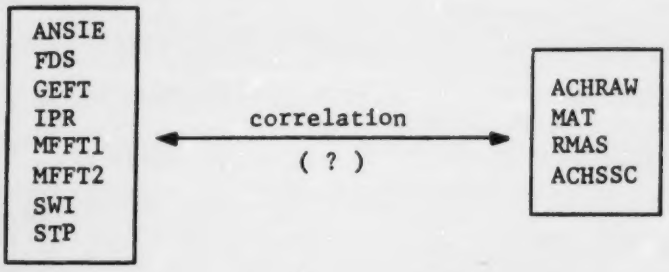


Figure 18. Model for canonical correlation for Hypothesis 2

Multiple correlational analyses served a two fold purpose: (1) to determine the multiple correlation, R, of the set of cognitive style variables with each of the following: achievement, aptitude, and attitudes. Diagramatically, this is shown in Figure 19.

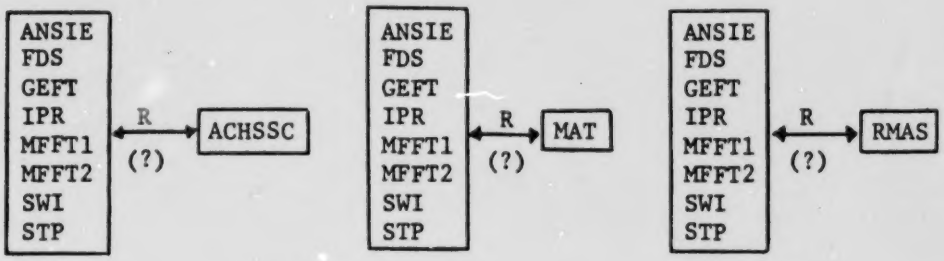


Figure 19. Model for multiple correlation for Hypotheses 3 and 4

By employing a stepwise regression and by examination of the partial correlations, the unique contributions of each cognitive style variable to the multiple correlation was assessed. The second purpose was (2) to derive a prediction or regression equation. Hypotheses 3 and 4 were investigated using the above analyses.

To examine the overall differences between groups (Hypothesis 5) a multivariate analysis of variance was conducted, followed by univariate tests--where appropriate. Following significant univariate tests, a post-hoc analysis of subgroup means was conducted using Tukey's multiple comparison procedures. Discriminant function analysis was used to provide additional insight into Hypothesis 5 as well as to investigate Hypothesis 6. The classification matrix, together with cognitive style variables that entered the discriminant function, provided a means to research Hypothesis 7.

A thorough and more detailed description of all the data analyses, with findings, is reported in Chapter IV. Discussion of findings together with summary, conclusions, and interpretations is reported in Chapter V.

CHAPTER IV

ANALYSIS OF DATA AND FINDINGS

Introduction

After a discussion of two analysis preliminaries--data editing and selection of α and power levels--this chapter presents the analyses of the data from the seven cognitive style measures, the intelligence measure, the three mathematics criterion measures, and the demographic variables. The data was analyzed in terms of the following five sub-analyses: (1) the product moment intercorrelations of all variables, (2) canonical correlational analysis between the two sets of variables, cognitive style dimensions and mathematics criterion variables, (3) multiple correlational analyses with the independent variables the cognitive style measures and the dependent variables, in turn, the three mathematics criterion measures, (4) multivariate analysis of variance with cognitive style measures as the independent variables, and (5) discriminant analyses.

Each hypothesis is stated, the analysis--or analyses--are discussed, and the findings relevant to that hypothesis or to the questions stated in Chapter I are presented. Further discussion of findings, together with summary and conclusions, are reported in Chapter V.

Data editing. The participating sample (185) was selected with n large enough to account for possible missing data, to allow for subject mortality, and to provide adequate n for the statistical analyses.

Excluding the demographic variables, a complete set of data per subject included measures on eight cognitive style dimensions, on intelligence, and on three mathematics criteria. Of 2035 measures (185 x 11), less than .75% of the data was missing. 182 subjects had a complete data set.

Having secured more than ample subjects, the computer packages BMD10M and BMDP7D (Dixon, 1975) were used to edit the data for markedly deviant scores. BMD10M screens multivariate data for outliers by computing Mahalanobis distances of each case from the center of the distribution. This information, supplemented by histograms and descriptive statistics for each group (provided by BMDP7D) helped identify seven outliers. Three marked outliers were excluded. To achieve equal n per subgroup, two subjects were randomly discarded. Analyses would then be conducted on 180 subjects (6 subgroups each with 30) with less than 7/10 of 1% missing data. (Raw data records for all subjects are listed in Appendix F.)

Alpha level and power analysis. With the primary intent to investigate relationships and interrelationships of cognitive style variables to the learning of mathematics, the exploratory study seeks general patterns and/or trends. To lessen the risk of failing to reject a null hypothesis because of a deficient experimental design, careful consideration must be given to both Type I (α) and Type II (β) error. Type I (α) error must be considered because many statistical tests will be made on the same data, thus an inflation effect. In view of the present status of cognitive style research, a Type II (β) error must be given at least equal consideration in that failure to reject a null hypothesis may obscure a potentially fruitful area for future investigation.

Type I (α) error is the error of rejecting the null hypothesis when the null hypothesis is true. Type II (β) error is the error of failing to reject the null hypothesis when the null hypothesis is false. The power of a test is the a priori probability ($1 - \beta$) of rejecting the null when the null is false--generally the primary interest of most research.

Several factors are interrelated when consideration is given to Type I error (α), Type II error (β), and power ($1 - \beta$). Clark (1977, p. 385) relates that the power depends on: (1) the statistical test used (since the distribution is of a statistical parameter ρ), (2) the significant level (α level) chosen (as α determines the size of the critical--rejection--region), (3) the sample size used, n, (since the standard error determines the critical value for a given α) and (4) the size of the difference that the experimenter expects to detect (expressed in standard error units). For a given statistical test, the four variables (α, n, size of the difference, and power) are related so that when any three are specified the fourth is uniquely determined.

"Cohen (1969) has simplified the problem of estimating the size of the difference by defining a unit called the 'effect size' (ES) which incorporates both the size of the difference and the population variance." (Clark, 1977, p. 386) The 'effect size' according to Cohen, is the extent to which the phenomena under investigation exist in the population of interest.

"With Cohen's tables, the experimenter may specify any three of the variables (α, n, ES, power) and find the corresponding value of the fourth variable in an appropriate table." (Clark, 1977, p. 386)

By determining " . . . what effect size is necessary to insure that the result is of practical significance (rather than just statistically significant), then Cohen's tables may be used to plan an experiment. A reasonable balance between the probability of both Type I and Type II error, and hence a reasonable chance for success, will be possible." (Clark, 1977, p. 387)

Specifically, in regard to the correlational phase of this study, Tables 6 and 7 illustrate the relation between Type I error, Type II error, power, effect size, and sample size. Table 6 refers to the pilot study and Table 7 refers to the major study.

Table 6

Relationship between Type I Error, Type II Error, Power, Effect Size, and Sample Size--Pilot Study

α	β	$1 - \beta$	E.S.	n
.01	.02	.98	.768	27
.05	.01	.99	.714	27

Table 7

Relationship between Type I Error, Type II Error, Power, Effect Size, and Sample Size--Major Study

α	β	$1 - \beta$	E.S.	n
.01	.022	.978	.356	180
.05	.017	.983	.320	180
.10	.010	.990	.280	180

Because the intent is to look for general patterns and/or relationships in the correlational phase, more liberal α levels and a large sample size were chosen in an effort to secure more statistical power. Correlations were made at the .001 level providing power greater than or equal to .95. Reasons for $\alpha = .001$ are discussed in the analysis of the 15 by 15 correlation matrix.

The regressional phase used significance levels of .05. The multivariate techniques, to explore question 3, provide an overall control of error; thus significance levels used were again .05.

The analysis proceeds by discussion of the results for the hypotheses in the same order in which they were presented in Chapter I.

Hypothesis 1: None of the following variables will exhibit first order correlations with any of the others in a significant manner:

The student's position on each cognitive style dimension:

(a) field articulation as measured by the Group Embedded Figures Test
(b) conceptual tempo as measured by the Matching Familiar Figures Test
(c) locus of control as measured by the Adult Nowicki-Strickland Internal External Scale
(d) preceptive-receptive as measured by the Symbols Test and Identical Pictures
(e) intuitive-systematic as measured by Scrambled Words and Following Directions

and the student's

(f) grade in the first required mathematics course
(g) mathematics achievement as measured by the Columbus Technical Institute Mathematics Placement Tests
(h) aptitude for mathematics as measured by the Mathematics Aptitude Test
(i) attitude toward mathematics as measured by the Revised Math Attitude Scale
(j) measure of intelligence as determined by Advanced Progressive Matrices

Analysis. To investigate question one concerning the correlational nature of the cognitive style dimensions, Pearson product-moment correlations were computed by use of the computer package SPSS: PEARSON CORR (Nie et al., 1975). Fifteen variables were represented in the correlation matrix: see Table 8.

In interpretation of the correlation matrix, the critical values for determining statistically significant correlations increases as the number of variables increases. With a large number of variables, some of the pair-wise correlations could be expected to be significant by pure chance alone. For instance, a correlation matrix of ten variables contains forty $\left(\frac{n(n-1)}{2}\right)$ separate unique correlations (not counting duplications or self correlations). For $\alpha = .05$, 5 out of 100, or 2 out of 40 correlations would be expected to be significant by chance alone.

For independent events, the collective probability of making one or more alpha errors (α_d) is given by:

$$(\alpha_d) = 1 - (1 - \alpha_a)^c$$

where α_a is the chosen alpha level, c the number of comparisons and α_d the desired alpha level.

For $\alpha = .05$ with 105 comparisons (c),

$$\alpha_d = 1 - (1 - .05)^{105}$$

$$\alpha_d = 1 - (.005) = .995$$

the collective alpha risk is .995! (When events, or comparisons, are not independent, α_d is a conservative estimate.) Similarly, for $\alpha_a = .01$, $\alpha_d = .652$; and for $\alpha_a = .001$, $\alpha_d = .099$.

Table 8

Pearson Correlation Coefficients for Variables in Hypothesis 1 (n = 180)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. HSMPI	1.000 (0.000)														
2. CTIGPA	0.205 (0.006)	1.000 (0.000)													
3. CTIMGP	0.094 (0.212)	0.274 (0.001)	1.000 (0.000)												
4. ANSIE	0.022 (0.771)	-0.244 (0.001)	-0.040 (0.591)	1.000 (0.000)											
5. FDS	0.189 (0.011)	0.343 (0.001)	0.114 (0.128)	-0.031 (0.683)	1.000 (0.000)										
6. GEFT	0.131 (0.080)	0.334 (0.001)	0.172 (0.021)	-0.004 (0.956)	0.413 (0.001)	1.000 (0.000)									
7. IPR	-0.010 (0.892)	0.074 (0.323)	0.017 (0.822)	0.021 (0.785)	-0.031 (0.684)	0.095 (0.204)	1.000 (0.000)								
8. MFFT1	-0.014 (0.852)	0.152 (0.041)	0.039 (0.602)	-0.010 (0.890)	0.059 (0.432)	-0.035 (0.638)	-0.151 (0.043)	1.000 (0.000)							
9. MFFT2	-0.044 (0.561)	-0.172 (0.021)	0.010 (0.897)	0.029 (0.704)	-0.255 (0.001)	-0.184 (0.013)	-0.070 (0.353)	-0.512 (0.001)	1.000 (0.000)						
10. SWI	0.189 (0.011)	0.188 (0.012)	0.092 (0.221)	-0.015 (0.844)	0.352 (0.001)	0.182 (0.014)	-0.008 (0.913)	-0.155 (0.037)	-0.013 (0.864)	1.000 (0.000)					
11. STP	-0.005 (0.949)	0.154 (0.039)	-0.212 (0.004)	0.015 (0.840)	-0.035 (0.639)	-0.014 (0.854)	0.364 (0.001)	-0.029 (0.698)	0.030 (0.691)	-0.028 (0.709)	1.000 (0.000)				
12. APM	0.253 (0.001)	0.465 (0.001)	0.212 (0.004)	-0.050 (0.504)	0.521 (0.001)	0.565 (0.001)	0.090 (0.229)	0.036 (0.627)	-0.318 (0.001)	0.195 (0.009)	-0.031 (0.683)	1.000 (0.000)			
13. ACH	0.324 (0.001)	0.375 (0.001)	0.132 (0.078)	-0.095 (0.207)	0.318 (0.001)	0.139 (0.063)	0.037 (0.623)	0.052 (0.491)	-0.084 (0.264)	0.296 (0.001)	-0.022 (0.771)	0.336 (0.001)	1.000 (0.000)		
14. APT	0.294 (0.001)	0.270 (0.001)	0.108 (0.149)	-0.092 (0.218)	0.595 (0.001)	0.366 (0.001)	-0.104 (0.166)	-0.001 (0.993)	-0.169 (0.023)	0.385 (0.001)	-0.035 (0.641)	0.472 (0.001)	0.435 (0.001)	1.000 (0.000)	
15. ATT	0.449 (0.001)	0.077 (0.306)	0.253 (0.001)	0.091 (0.226)	0.132 (0.077)	0.085 (0.254)	0.022 (0.765)	-0.013 (0.860)	-0.036 (0.632)	0.096 (0.201)	-0.116 (0.120)	0.243 (0.001)	0.349 (0.001)	0.283 (0.001)	1.000 (0.000)

Note: Level of statistical significance for a two-tailed test is in parenthesis. (These statistics refer to statement confidence levels.)

What is needed is a method to control the alpha-levels for each comparison to assure an overall desired alpha-level. The procedure to select these alpha-levels is discussed below.

Alpha-levels are closely related to the construction of confidence intervals. For example, a 5 percent or .05 level of confidence as a rejection criterion is accompanied by a 95% confidence interval.

Suppose c parameters, r_1, r_2, ... , r_c, each have a 95% confidence interval. If the r_i are independent, the probability for r_1 and r_2 and . . . and r_c to be correct would be $(.95)^c$. For the correlation matrix, however, r_1, r_2, ... , r_c are not independent because many correlations were from the same set of sample data.

A family confidence coefficient is needed rather than a statement confidence coefficient. "The latter is the familiar type of confidence coefficient . . . which indicates the proportion of correct estimates that are obtained when repeated samples are selected and the specified confidence interval is calculated for each sample. A family confidence coefficient, on the other hand, indicates the proportion of correct families of estimates when repeated samples are selected and the specific confidence intervals for the entire family are calculated for each sample . . . A procedure which provides a family confidence coefficient is often highly desirable since it permits the analyst to weave the separate results together into an integrated set of conclusions, with an assurance that the entire set of estimates is correct." (From Applied Linear Statistical Models

by Neter and Wasserman, 1974, p. 141)

A generalization of the Bonferoni inequality provides such a family confidence coefficient. Let A_i = the event that the i confidence interval does not cover r_i. If the probability of $A_i = \alpha$, (i.e. $p(A_i) = \alpha$), then $p(\overline{A_i}) = 1 - \alpha$.

Therefore, $p\left(\bigcap_{i=1}^{c} \overline{A_i}\right) = (1 - \alpha)^c \geq 1 - c\alpha$

Thus, if c interval estimates are desired with family confidence coefficient = $1 - \alpha$, constructing each interval estimate with statement confidence coefficient = $1 - \frac{\alpha}{c}$ will suffice.

For a 95% confidence interval, $\alpha = .05$, and with $c = 105$, $\frac{\alpha}{c} = 0.000476 \approx .0005$. This statement confidence level of .0005 corresponds to the actual α-level needed in order to obtain an overall desired α-level of .05 (family confidence α-level). Coupled with earlier discussions on the direct relationship between power $(1 - \beta)$ and α, the decision was made to use a somewhat more liberal α-level equal to .001 as the statement confidence α-level. (This statement confidence α-level is the same as the α level used when testing separate, independent, strictly pairwise relations.) The family confidence coefficient equals .099.

With a family confidence α-level $<$ .10, the effect size from Cohen's power analysis tables should be $>$ .280.

To calculate the critical values of r, using a statement confidence α-level = .001, the t distribution was used, which is an appropriate model for testing the null hypothesis that the population correlation coefficient is zero.

The t-statistic may be calculated from

$$\underline{t} = r_{xy}\sqrt{\frac{N-2}{1-r_{xy}^2}}$$

with $\underline{df} = N - 2$. To transform critical values of t to critical values of $\underline{r}$ (i.e. when α-levels $<$ tabled α-levels),

$$r_{xy} = \sqrt{\frac{t^2}{N-2+t^2}}$$

with $\underline{df} = N - 2$.

With the α-level = .001, for a two-tailed test, the .9995 percentile in Student's t-distribution is 3.291, $\underline{df} = \infty$. Calculation, using the above formula, yields a critical $r_{xy} = .239$. With the more conservative df = 120, ${}_{.9995}t_{120} = 3.373$. Calculation yields a critical $r_{xy} = .294$. The more conservative $\underline{df}$ yield a more stringent $\underline{r}$ value, which also exceeds the needed correlation under effect size ($\underline{r} = .280$).

For comparative purposes, a Bonferroni t-statistic was estimated for $\underline{df} = 178$ from tabled values with $\underline{df} = 30$, 40, 60, and 120. With .0005 as the statement confidence α-level (.05 as the family confidence α-level), a critical value for $\underline{r}$ was .257.

The critical value, $\underline{r} = .294$ ($\alpha = .001$, $\underline{df} = 120$) will be used for statistical significance in the correlational phase of this study.

Findings. Because 31 of the possible 105 correlations were statistically significant ($\underline{p} < .001$), Hypothesis 1 was rejected. From the correlation matrix, those correlations greater than .294 (critical values for statement confidence level = .001, $\underline{df} = 120$) are reported. With the purpose of the total correlation matrix being to

explore for any existing relations between variables, several "pair-wise" correlations are also reported and discussed for selected variables. (Pair-wise refers to strictly pair-wise relations as viewed as independent statistical tests of significance.)

Figure 20 depicts all significant intercorrelations among the eight measures of cognitive style. Using the critical values, adjusted for the number of variables, four significant correlations are reported.

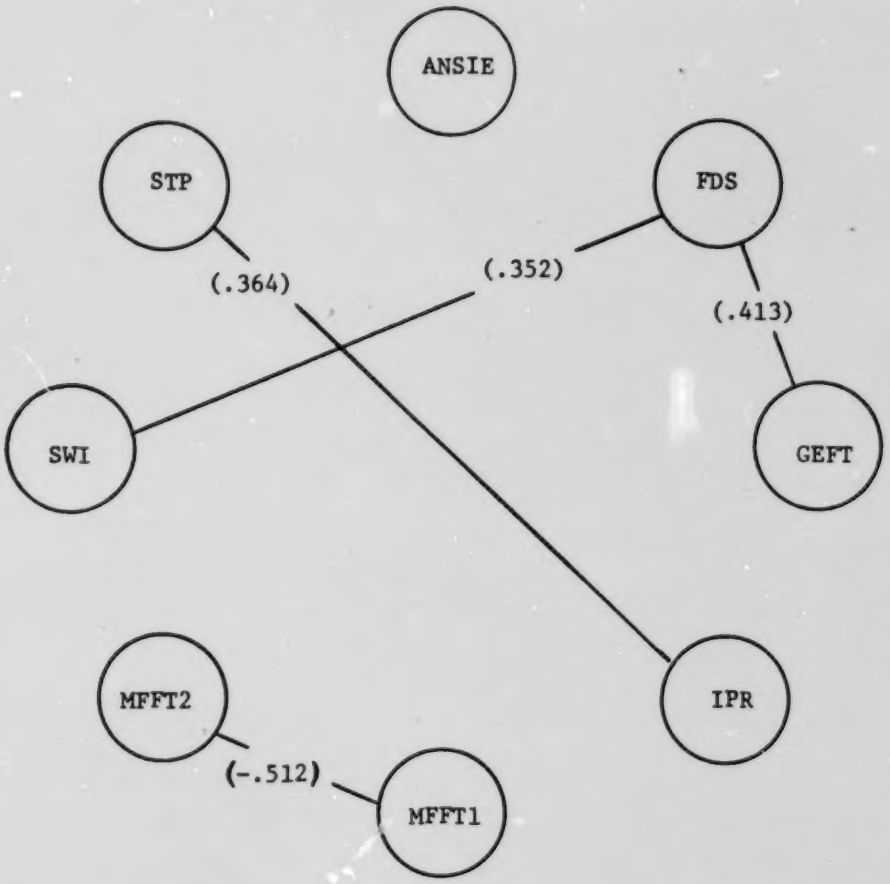


Figure 20. Significant intercorrelations among cognitive style measures (α = .001, df = 120).

The locus of control (ANSIE) measure appears to be independent of the remaining measures. The systematic measure (FDS) is related positively to both the field dependence-independence measure (GEFT) (r = .413, p < .001) and to the intuitive measure (SWI) (r = .352, p < .001).

The preceptive (STP) and receptive (IPR) measures, which represent extremes of the information gathering dimension in the McKenney model, are significantly correlated in a positive direction (r = .364, p < .001). The information evaluation dimension of the McKenney model has at the extremes of the continuum systematic vs. intuitive measures; yet as noted above, these two are also significantly correlated in a positive direction (r = .352, p < .001).

The two measures of conceptual tempo, mean latency of initial response (MFFT1) and mean error score (MFFT2), are significantly correlated in a negative direction--as was anticipated and also purported by prior research studies (r = -.521, p < .001).

Of interest is the relative independence of the four subsets (field articulation, conceptual tempo, the McKenney model, and locus of control) of cognitive style dimensions to each other. Field articulation is only related to one dimension of the McKenney model. Conceptual tempo is unrelated to any of the remaining three sets. The McKenney model shows intercorrelations among its dimensions, but only one correlation with another subset (FDS, GEFT). Locus of control is unrelated to the other three subsets.

Figure 21 depicts additional intercorrelations among the same eight dimensions. Those correlations, that would be significant

at the .01 and .05 levels when viewed in a strictly "pair-wise" fashion, are reported. Viewed independently these correlations consequently need smaller critical values for significance (r = .148, p < .05, pair-wise; and r = .194, p < .01, pair-wise). Only five correlations supplement the four depicted in Figure 20.

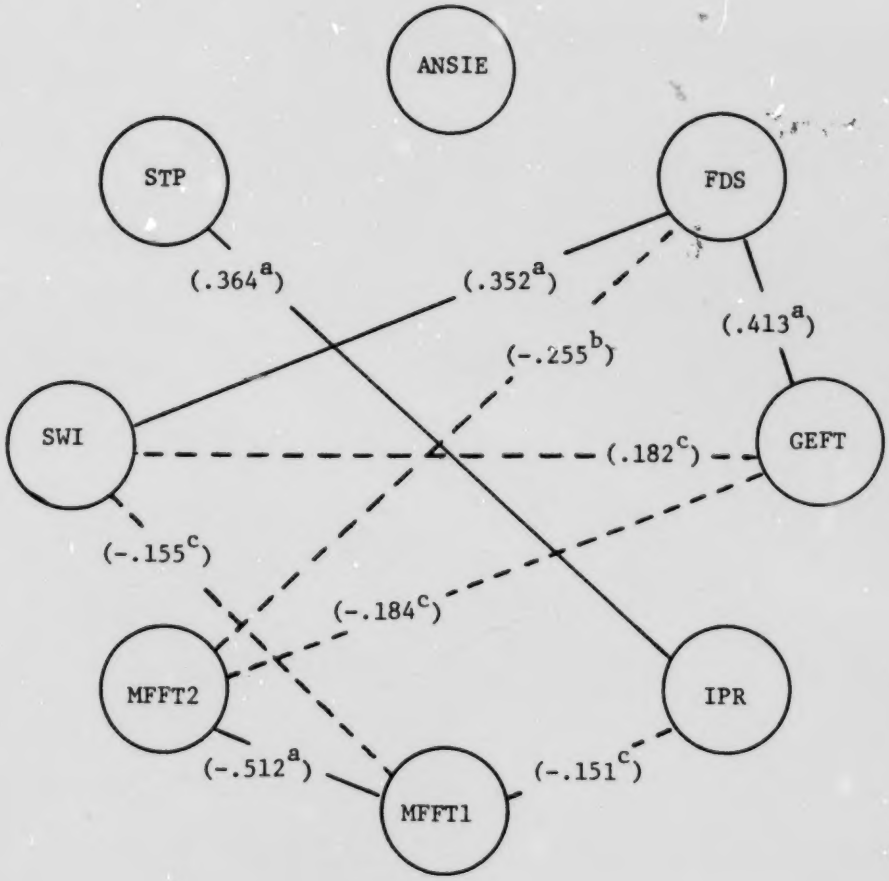


Figure 21. Significant "pair-wise" intercorrelations among the cognitive style measures.

[a]Significant with statement confidence level (α = .001, df = 120).
[b]Significant when considered as pair-wise (p < .01).
[c]Significant when considered as pair-wise (p < .05).

The five additional correlations show the systematic measure (FDS) now relating to conceptual tempo (MFFT2) in a negative direction ($r = -.255$, $p < .01$); field articulation (GEFT) relating to both the intuitive measure (SWI) ($r = .182$, $p < .05$), and to conceptual tempo (MFFT2) ($r = -.184$, $p < .05$); and the intuitive measure (SWI) relating to conceptual tempo (MFFT1) ($r = -.155$, $p < .05$). Because of the more liberal critical values, caution must be exercised in interpretation of these five additional correlations.

Relating the findings from Figure 21 to Figure 20: field articulation (GEFT) and the systematic measure (FDS) are highly correlated. In Figure 21, both are then negatively correlated to conceptual tempo (MFFT2). Both field articulation (GEFT) and the intuitive measure (SWI) are significantly correlated with the systematic measure (FDS). In Figure 21 then, GEFT and SWI show a modest inter-correlation. Locus of control remains uncorrelated to all remaining dimensions in both figures.

In a predictive, or multiple regressional sense, the ideal setting would be to derive a regression equation

$$\hat{Y} = a_1X_1 + a_2X_2 + \ldots + a_nX_n + C$$

such that the independent variables are each significantly and highly correlated with the criterion variable, yet are not significantly correlated with each other. (The relative independence of the independent variables assures that more unique variance of the criterion variable may be "explained" or "accounted for".)

From Figure 20, the cognitive style dimensions do seem relatively independent of each other. Table 9 lists all the cognitive style dimensions that significantly correlate with the three mathematics criterion variables.

Table 9

Significant Correlations of the Cognitive Style Dimensions with the Mathematics Criterion Measures

Mathematics Criterion Variables	Significant Correlations
Achievement (ACH)	FDS (.318[a]); SWI (.296[a])
Aptitude (APT)	FDS (.595[a]); SWI (.385[a]); GEFT (.366[a]); MFFT2 (-.169[b])
Attitude (ATT)	none

a - significant with statement confidence level, $\alpha = .001$, df = 120
b - significant when considered as "pair-wise" ($p < .05$)

Utilizing the square of the correlation coefficient, the coefficient of determination explains the percent of variance accounted for in one variable by a knowledge of the correlated variable. Diagramatically, the percent of common factor variance in achievement and aptitude is shown by Venn diagrams.

FDS, the systematic measure, correlated with achievement (.318); $(.318)^2 = .101$ percent of variance in achievement was accounted for by this dimension. SWI correlated with achievement (.296); $(.296)^2$ or .088 percent of variance in achievement was accounted for by the

intuitive measure. However, because FDS and SWI are intercorrelated (.352), some variance in achievement is common to both FDS and SWI. These relationships are depicted in Figure 22. The relationships are analyzed further under multiple regression analysis using a procedure called commonality analysis.

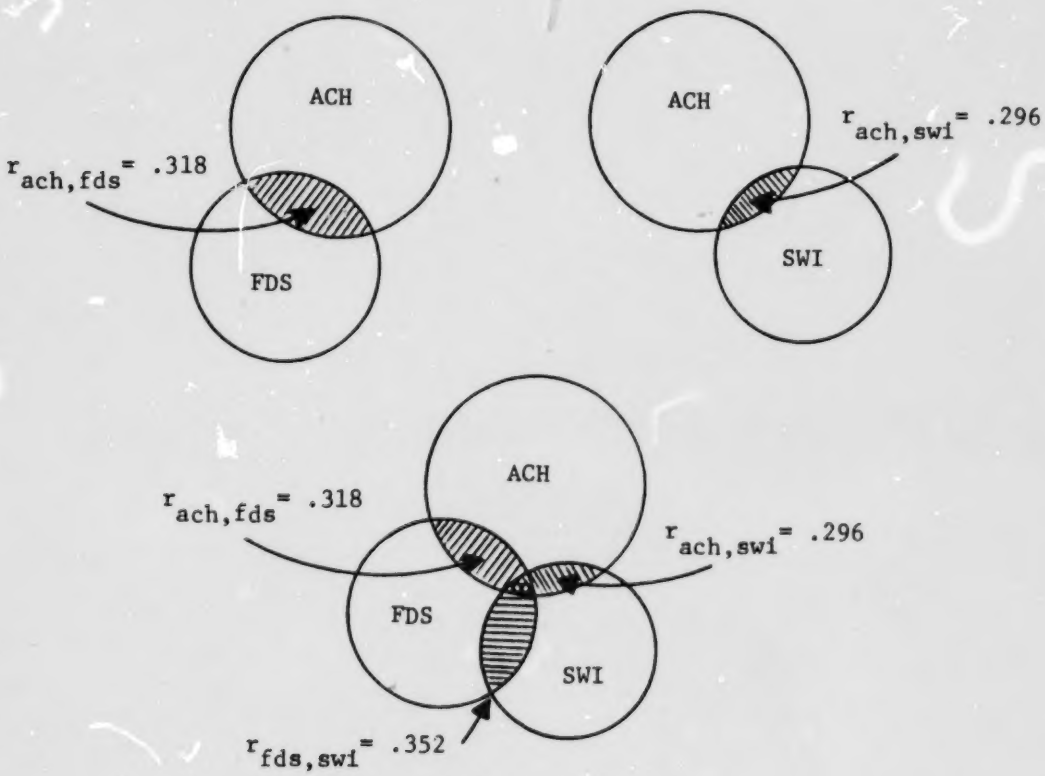


Figure 22. Venn diagram relating mathematical achievement to the systematic and intuitive dimensions

Mathematics aptitude has four correlates--three significant correlates when the more conservative critical values are used. Aptitude correlates significantly with the systematic measure (FDS, $r = .595$, $p < .001$), with the intuitive measure (SWI, $r = .385$, $p < .001$), and with field articulation (GEFT, $r = .366$, $p < .001$). A modest negative "pair-wise" correlation exists between aptitude and the number of errors on the conceptual tempo measure (MFFT2, $r = -.169$, $p < .05$). Figure 23 depicts the relationship of these cognitive style dimensions to aptitude, by analyzing the variance in aptitude accounted for by FDS, SWI, and GEFT.

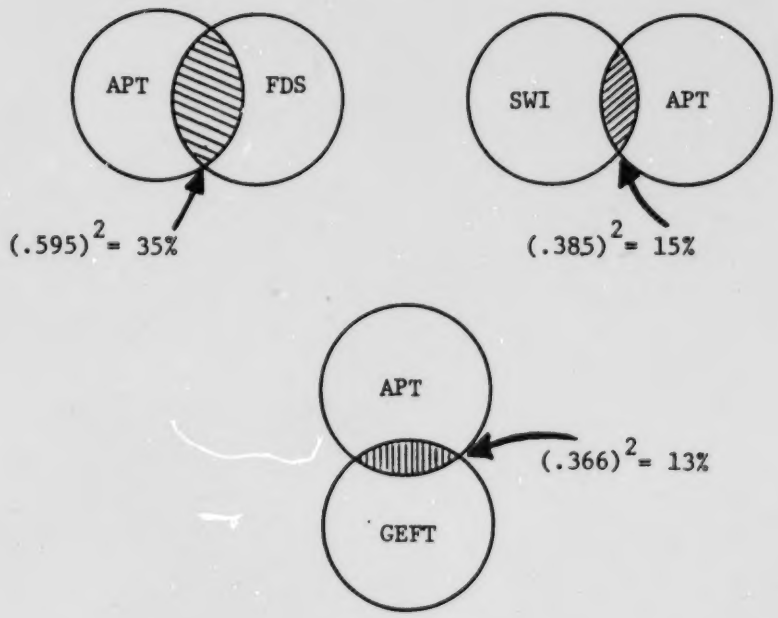


Figure 23. Venn diagram relating aptitude for mathematics to the systematic, intuitive, and field articulation measures

Caution must be exercised, however, in attributing 35% of the common factor variance in aptitude solely to the systematic measure (FDS) and 15% solely to the intuitive measure (SWI), and 13% solely to the field articulation measure (GEFT). Figure 24 depicts the intercorrelations among FDS, SWI, and GEFT.

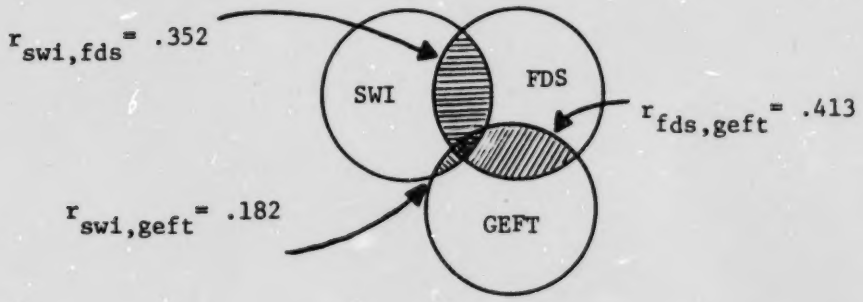


Figure 24. Venn diagram of intercorrelations among the sytematic, intuitive, and field articulation measures

To analyze the unique contributions of each of the cognitive style dimensions to aptitude, partial correlations and semi-partial correlations will be obtained by using multiple correlation analysis.

Interpretation at this point in the analyses would imply that students who tend to be more systematic (problem solving approach incorporates devising a plan for solution), intuitive (problem solving approach incorporates trial-and-error), and field independent (problem solving approach characterized by an analytic differentiated approach), also tend to have a higher aptitude for mathematics (ability to select and organized relevant information for the solution of a problem).

None of the cognitive style dimensions correlated significantly with attitudes toward mathematics--even when viewed in a strict pair-wise fashion.

Table 10 lists all variables that significantly correlated with the general reasoning, or intelligence, measure (APM).

Table 10

Significant Correlates of Intelligence

Intellectual Efficiency	Significant Correlations
APM	CTIGPA (.465)
	FDS (.521)
	GEFT (.565)
	MFFT2 (-.318)
	ACH (.336)
	APT (.472)

Significant with statement confidence level $\alpha = .001$, $df = 120$

In addition to the interpretative complications contributed by the intercorrelations among the significant correlates of mathematics aptitude, intelligence (APM) is significantly correlated with both aptitude (.472) and the two measures of cognitive style (FDS, $r = .521$; and GEFT, $r = .565$).

Findings from prior research (Black, 1977; Erginell, 1970; Fein, 1970; and Satterly, 1976) are substantiated in the fact that the possible confounding effects of intelligence must at least be considered when researching the cognitive style dimensions. More insight into the actual role played by intelligence will be gained under the multiple correlational analysis and the discriminant analysis (Hypothesis 4 and

Hypothesis 6).

Intelligence is also significantly correlated with student's grade point average, as might be anticipated. If the correlations are viewed in the more liberal "pair-wise" fashion, intelligence also correlated positively with high school mathematics product index (r = .253, $p < .01$), college mathematics grade point (r = .212, $p < .01$), the intuitive measure (r = .195, $p < .01$), and attitudes toward mathematics (r = .243, $p < .01$).

Other significant ($p < .001$) correlates with intelligence include mathematics achievement (r = .336) and the number of errors on the conceptual tempo measure (r = -.318).

Additional correlations of interest are the intercorrelations of the mathematics criterion variables: achievement, aptitude, attitudes, high school mathematics product index, and college mathematics grade point average, given in Table 11.

Table 11

Intercorrelations Among Mathematics Criterion Variables

	1	2	3	4	5
1. HSMPI	1.000				
2. CTIMGP	0.094	1.000			
3. ACH	0.324	0.132	1.000		
4. APT	0.294	0.108	0.435	1.000	
5. ATT	0.449	0.253	0.349	0.283	1.000

Achievement in mathematics is significantly correlated with aptitude ($r = .432$, $p < .001$), attitudes ($r = .349$, $p < .001$), and high school mathematics product index ($r = .324$, $p < .001$).

Aptitude for mathematics correlated significantly with high school mathematics product index ($r = .294$, $p < .001$), attitudes ($r = .349$, $p < .001$) , and achievement.

Attitudes toward mathematics were significantly correlated with high school mathematics product index ($r = .449$, $p < .001$), and mathematics achievement.

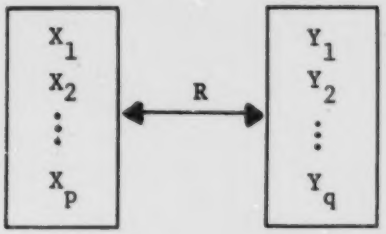
To provide additional information, other than the zero order product moment correlations, multiple correlation coefficients (R) were computed using both canonical correlations (computer packages BMDP6M (Dixon, 1975), and SPSS: CANCORR (Nie et al., 1975)) and multiple regressions (computer packages BMDP1R and BMDP2R (Dixon, 1975)).

The canonical correlation analysis provided insight into the relationship that a subset of the cognitive style dimensions might have to a subset of the mathematic criterion measures. The possibility exists for variables to have negligible or low correlations when viewed separately, yet when combined or "pooled" in sets, the combinations may yield significantly high correlations. Analysis of the data using canonical correlationals provided more information for question one in the problem statement, and served to test Hypothesis 2.

Hypothesis 2: The subset of scores from the cognitive style dimensions will not exhibit a significant canonical correlation with the subset of scores from mathematics achievement, aptitude, and attitudes.

Analysis. Canonical correlation analysis is loosely characterized as a "sort of 'double barrelled principal components analysis'. It identified the 'components' of one set of variables that are most highly related (linearly) to the 'components' of the other set of variables." (Tatsuoka, 1971, p. 183)

Diagrammatically, a correlation is sought between two sets of variables.



A linear combination is constructed for each set of variables. For instance,

$$Z = \sum_{i=1}^{p} a_i X_i \quad \text{and} \quad W = \sum_{j=1}^{q} b_j Y_j$$

Statistically, weighted coefficients (a_i and b_j) are determined for each of the two sets of variables so as to maximize the correlation (r_{zw}) between the two linear combinations; r_{zw}, the correlation to be maximized is known as a canonical correlation. This pair of linear combinations is known as canonical variates. Many such pairs of canonical variates may be derived, each yielding a canonical correlation. The number of canonical-variate pairs will equal the number of variables in the smaller set. (This is because the rank of the quadruple matrix, $S_{xx}^{-1} S_{xy} S_{yy}^{-1} S_{yx}$, whose eigenvalues and eigenvectors determine the canonical variates, is equal to p or q, whichever is smaller--Tatsuoka, 1971, p. 186.

Analogous to the technique in principal component analysis, each successive pair of canonical variates accounts for residual variance (variance unaccounted for by preceding variates). The canonical-variate pairs are individually tested for statistical significance if there is any significant linear relationship between the two sets of variables.

To test Hypothesis 2, canonical correlations were obtained by using the computer package SPSS: CANCORR (Nie et al., 1975). The model is depicted in Figure 25.

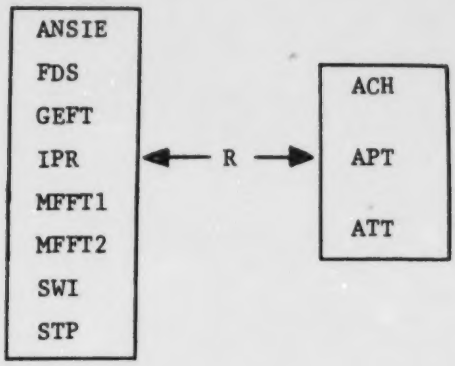


Figure 25. Canonical correlational analysis model.

Table 12 lists the canonical correlations for these two sets.

Table 12

Canonical correlations: Set of cogntive style variables with the set { ACH, APT, ATT }

Number	Eigenvalue	Canonical correlation	Wilk's lambda	Chi-square	D.F.	Significance
1	0.437	0.661	0.518	113.857	24	0.000
2	0.048	0.219	0.919	14.568	14	0.408
3	0.035	0.186	0.965	6.085	6	0.414

A statistically significant canonical correlation (r_{zw} = .661, $p < .001$) exists between the set of cognitive style dimensions and the

set of mathematics criterion measures; therefore, Hypothesis 2 is rejected. However, only the first, of three possible, canonical correlation was significant.

To determine significance, Bartlett's chi-square or Rao's F-ratio could be used; these are similar for large samples (Stevens, 1979). Bartlett's chi-square approximation is:

$$V = - \left[N - 3/2 - (p + q)/2 \right] \ln \Lambda$$

or, in terms of the eigenvalues:

$$V = - \left[N - 3/2 - (p + q)/2 \right] \sum_{j=1}^{r} \ln(1 - u_j^2)$$

where N is the sample size, p and q are the number of variables in each set, and Λ is Wilks' lambda. Each term in the sum of V is an approximate chi-square. "For each j :

$$V_j = - \left[N - 3/2 - (p + q)/2 \right] \sum_{j=1}^{r} \ln(1 - u_j^2)$$

is distributed approximately as a chi-square with $p + q - (2j - 1)$ degrees of freedom." (Tatsuoka, 1971, p. 189)

To test the cumulative difference of the canonical-variate pairs, the successive test statistics are summarized from the table in Tatsuoka, 1971, p. 189.

Residual after removing	χ^2 - Approximate statistic	Number of degrees of freedom
first canonical pair	$V - V_1$	$pq - (p + q - 1) = (p - 1)(q - 1)$
first two canonical pairs	$V - V_1 - V_2$	$(p - 1)(q - 1) - (p + q - 3) = (p - 2)(q - 2)$
first three canonical pairs	$V - V_1 - V_2 - V_3$	$(p - 2)(q - 2) - (p + q - 5) = (p - 3)(q - 3)$
⋮	⋮	⋮

Having determined the significance of the first canonical correlation (r = .661) between the cognitive style dimensions and the mathematics criterion measures, the next step is interpretation of the first pair of canonical variates.

Two techniques advocated for interpreting the canonical variates are (a) to examine the standardized coefficients of the variates, and (b) to examine the canonical variate-variable correlations (canonical components). (Barcikowski & Stevens, 1975, p. 353) Because different views exist on which technique is preferable (see Meredith, 1964, p. 55 and Darlington et al., 1973, p. 443), both weightings are listed for comparative purposes.

The coefficients for the canonical variables for each set are given in Table 13; column I represents the relative weightings of the variable by standardized coefficients and column II represents the weightings by canonical variate-variable correlations. Column I was obtained from the computer package SPSS: CANCORR (Nie et al., 1975); column II from BMDP6M (Dixon, 1975).

Table 13

Weightings (coefficients) for the Canonical Variables

Cognitive style variables	Weightings I (rank)	II (rank)	Mathematics criterion	Weightings I	II
ANSIE	-0.148 (5)	-0.179 (5)	ACH	0.176	0.536
FDS	0.690 (1)	0.909 (1)	APT	0.949	0.983
GEFT	0.203 (3)	0.542 (3)	ATT	-0.153	0.176
IPR	-0.171 (4)	-0.144 (6)			
MFFT1	-0.024 (8)	0.016 (8)			
MFFT2	-0.062 (7)	-0.257 (4)			
SWI	0.325 (2)	0.610 (2)			
STP	0.073 (6)	-0.029 (7)			

Findings. Research does suggest that when variables within a set are highly intercorrelated, preference should be given to interpretation of the canonical variate-variable correlations. The interpretation, then--based on a significant canonical correlation ($r = .661$, $p < .001$)--would be that students characterized as systematic, intuitive, and field independent tend to have a higher aptitude for mathematics and tend to be higher achievers. This supports the finding evolved from the correlation matrix analysis.

However, are correlations ($r_{fds,geft} = .413$, and $r_{apt,ach} = .435$) to be considered "high"? While a subjective interpretation, even if these correlations are not considered "high", utilizing the weightings from the first technique does not alter the findings appreciably. The only alteration would be the exclusion of achievement in the interpretation. Examination of both techniques of weighting reveals the cognitive style variables occupy the same relative positions. A Spearman rank-order correlation coefficient (Rho) was computed yielding the significant correlation $\rho = .883$ ($p < .001$).

If achievement is eliminated, then one set consists of a single variable. The canonical correlation reduces, at most, to a multiple correlation. This possibility will be checked in the multiple regression analysis.

Interpretation, without considering achievement, would indicate that students characterized as systematic, intuitive, and field independent would tend to have a higher aptitude for mathematics.

To gain further insight into the correlative--as well as the predictive--nature of the cognitive style dimensions, multiple regression

analyis was used. (Computer packages SPSS: REGRESSION (Nie et al., 1975), BMDP1R and BMDP2R (Dixon, 1975))

In the regression analysis the independent variables were the cognitive style dimensions and the criterion variables were, in turn, mathematics achievement, aptitude for mathematics, and attitudes toward mathematics. This technique would provide an answer to question two from the problem statement concerning the predictive nature of the cognitive style dimensions.

Question 2) Which cognitive style dimensions, separately or combined, are significant predictors of (a) achievement in mathematics, (b) aptitude for mathematics, and (c) attitudes toward mathematics?

More important for this research than the derivation of a prediction equation(s) and evaluation of prediction accuracy, was a more thorough analysis of the correlational nature and structural relations of the cognitive style dimensions. The regression analysis, employing a stepwise procedure, served to evaluate the overall contributions of the independent variables to each of the criterion variables. The intent is modeled in Figure 26.

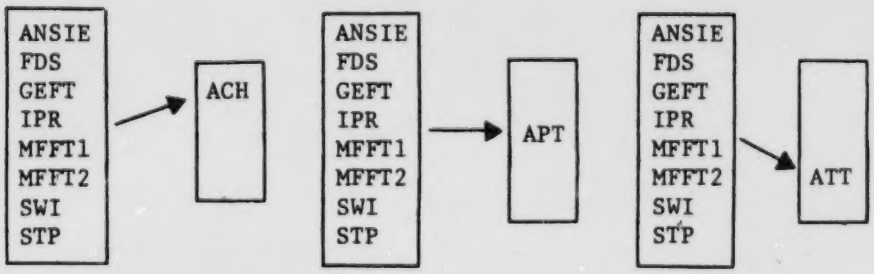


Figure 26. Multiple regression analysis model.

In addition, attention given to the partial and semi-partial correlation coefficients may help in ascertaining the relative and unique

contributions of each of the cognitive style dimensions while controlling for the influence of the remaining dimensions. These analyses were used to test Hypotheses 3 and 4.

Hypothesis 3: None of the cognitive style dimensions will make a significant contribution to the multiple correlation with:

(a) mathematics achievement
(b) aptitude for mathematics
(c) attitudes toward mathematics

Analysis. The general form of a regression equation is:

$$\hat{Y} = B_1X_1 + B_2X_2 + B_3X_3 + \ldots + B_nX_n + C$$

where $\hat{Y}$ represents the estimated values for the criterion variable Y, B_i are the regression coefficients, X_i are the independent variables, and C is the Y intercept.

Because the independent variables are measured in different units the relative importance of each independent variable is difficult to determine on the basis of the B_i values alone. A standardized regression equation would be:

$$Y = \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \ldots + \beta_nX_n$$

The β_i are standardized partial regression coefficients (beta weights). β_i are related to B_i by the relation,

$$\beta_i = \frac{s_i}{s_y} B_i$$

where s_i is the standard deviation of X_i, and s_y that of Y. "The $BETA_i$ coefficients can be interpreted as the number of standard deviations of Y that $\hat{Y}$ will change in response to an increase of one standard deviation in X_i (other independent variables being held constant)." (Wesolowsky, 1976, p. 59, 60)

The Pearson product moment correlation between Y and $\hat{Y}$ is called the multiple correlation coefficient, R.

Standardized regression equations for each of the criterion variables: mathematics achievement (ACH), aptitude for mathematics (APT), and attitudes toward mathematics (ATT) are given in Table 14.

The multiple correlation coefficients for the cognitive style dimensions (full model, c) with achievement, aptitude, and attitudes, respectively are R = .397, R = .651, and R = .212. These multiple correlation coefficients may be interpreted much like ordinary coefficients of correlation; however, R^2 is more meaningful and useful. R^2 is referred to as the coefficient of multiple determination and is a measure of the percent of variance in Y accounted for by the least squares combination of the independent variables.

Tests of statistical significance of the multiple correlations are done using an F test with K and N - k - 1 degrees of freedom.

$$F = \frac{R^2 / k}{(1 - R^2)/(N - k - 1)}$$

N = sample size and k = the number of independent variables.

For both achievement and aptitude, R^2 is significant at the .01 level; for attitude R^2 is not statistically significant (R^2= 0.05, $p < .39$, df = 8, 171). Discussion of the criterion measures, achievement and aptitude follows.

While for both achievement and aptitude, the multiple correlations (for the full model) were significant, the question remains: does each cognitive style dimension contribute a statistically significant increment in R^2 when entered in the regression equation? For each

Table 14

Standardized Regression Equations: Mathematics Achievement, Aptitude, and Attitude

Criterion		Standardized regression equation	Coefficient of determination	Standard error of estimate	Significance of regression
ACH	(a)	$\hat{Y} = (0.244)FDS + (0.210)SWI$	$R^2 = 0.14$	9.19	$.99F_{2,177} < 14.42$
	(b)	$\hat{Y} = (0.29)APM1 + (0.24)SWI$	$R^2 = 0.17$	9.04	$.99F_{2,177} < 17.92$
	(c)	$\hat{Y} = (-0.09)ANSIE + (0.24)FDS + (0.001)GEFT + (0.08)IPR + (0.11)MFFT1 + (0.04)MFFT2 + (0.23)SWI + (-0.03)STP$	$R^2 = 0.16$	9.25	$.99F_{8,171} < 3.998$
APT	(a)	$\hat{Y} = (0.471)FDS + (0.195)SWI + (0.136)GEFT$	$R^2 = 0.41$	3.54	$.99F_{3,176} < 39.93$
	(b)	$\hat{Y} = (0.219)APM1 + (0.412)FDS + (0.198)SWI$	$R^2 = 0.42$	3.48	$.99F_{3,176} < 43.28$
	(c)	$\hat{Y} = (-0.07)ANSIE + (0.45)FDS + (0.15)GEFT + (-0.12)IPR + (-0.04)MFFT1 + (-0.05)MFFT2 + (0.19)SWI + (0.03)STP$	$R^2 = 0.42$	3.54	$.99F_{8,171} < 15.68$
ATT	(a)	none entered			
	(b)	$\hat{Y} = (0.243)APM1$	$R^2 = 0.06$	17.76	$.99F_{1,178} < 11.14$
	(c)	$\hat{Y} = (0.10)ANSIE + (0.10)FDS + (0.03)GEFT + (0.07)IPR + (-0.002)MFFT1 + (0.001)MFFT2 + (0.05)SWI + (-0.14)STP$	$R^2 = 0.05$	18.23	$.61F_{8,171} < 1.06$

(a) stepwise regression with cognitive style variables that had significant F values ($p < .05$) for entry

(b) stepwise regression as in (a), except the intelligence measure was forced to enter first

(c) regression equation with all cognitive style variables entered (full model)

of the criterion variables, another F test was also made at each stage of the regression to determine whether an increment in R^2 attributed to a given variable is statistically significant ($p < .05$). The F test--

$$F = \frac{(R^2_{y.12...p} - R^2_{y.12...q}) / (p - q)}{(1 - R^2_{y.12...p}) / (N - p - 1)}$$

where $R^2_{y.12...p}$ = the squared multiple correlation coefficient for the regression of Y on p variables (larger coefficient); and $R^2_{y.12...q}$ = the squared multiple correlation coefficient for the regression of Y on q variables (smaller coefficient)--helps to determine the relative efficacies of different variables in the regression equation.

Table 15 lists, for each statistically significant cognitive style dimension, the criterion, the increase in percentage of variance accounted for ($R^2\Delta$), the F ratio and corresponding probability level exceeded (F and p), and the multiple correlation at each step.

Table 15

Stepwise Regression Results: Achievement, Aptitude, and Attitudes Regressed on Cognitive Style Dimensions (N = 180)

Criterion	Step	Dimension entered	$R^2\Delta$	F	p	R
ACH	1	FDS	0.101	10.765	.005	0.318
	2	SWI	0.039	7.970	.01	0.374
APT	1	FDS	0.354	49.155	.001	0.595
	2	SWI	0.035	9.837	.01	0.624
	3	GEFT	0.015	4.523	.05	0.636
ATT	none entered					

Having determined the statistical significance of the cognitive style dimensions, determination of the relative importance of the explanatory variables remains to be done.

"The problem of the relative contribution of independent variables to a dependent variable or variables is one of the most complex and difficult of regression analysis. It seems that no really satisfactory solution exists, at least when the independent variables are correlated." (Kerlinger, 1973, p. 621) "In both analyses (multiple regression analysis and discriminant analysis) the variables act in concert and cannot logically be separated to determine how much each variable contributes to prediction or to a discriminant function. Thus an index of absolute contribution is, considering the present state of knowledge, out of question. An index of relative variable contribution is, however, an approach advanced by many researchers." (Huberty, 1975, p. 63)

Traditionally, several indices have been used to gauge the contribution of a variable. "The two most frequently encountered criteria are the relative contribution to the proportion of variance accounted for in the dependent variable, and the relative magnitude of the squared β's." (Kerlinger & Pedhazur, 1973, p. 296)

In the context of the remarks by Kerlinger and Huberty, the following tentative findings must be interpreted with reservation and care.

Findings. For mathematics achievement, R = .397 and R^2= .158. If the total variance in achievement is 100%, the eight cognitive style dimensions (full model) account for 15.8% of this variance. However, as can be seen from the first regression equation, 14% (of the 15.8%)

is accounted for by the two dimensions: systematic (FDS) and intuitive (SWI).

The zero-order correlation, discussed earlier, of FDS with ACH was .318, or $(.318)^2 = 10.1\%$ of variance was accounted for by FDS. SWI correlated .296 with ACH, or $(.296)^2 = 8.8\%$ of the variance was accounted for by SWI. If the combined contribution to the explanation of the variance in achievement is 14%, then FDS and SWI share some explained variance in achievement. To analyze the variance of achievement into unique variances and common variance, commonality analysis was used. (A full discussion of commonality analysis is contained in Multiple Regression in Behavioral Research, Kerlinger & Pedhazur, 1973.)

Commonality analysis, by using the squared semi-partial correlations between achievement and the cognitive style dimensions: systematic and intuitive, expresses the explained variance in achievement as a composite of the unique contribution for each dimension plus its commonalities with the other dimensions. Table 16 summarizes the commonality analysis for mathematics achievement. (Refer also to the earlier Venn diagrams.)

Table 16

Summary of Commonality Analysis
(for Achievement)

	Dimensions	
	FDS	SWI
Unique to FDS	0.052	
Unique to SWI		0.039
Common to FDS and SWI	0.049	0.049
$\sum$:	0.101	0.088

10.1% of the variance in achievement is attributed to the systematic measure, FDS--composed of 5.2% unique variance and 4.9% variance shared with the intuitive measure, SWI. Of the 8.8% variance attributed to SWI, only 3.9% is unique to the intuitive measure.

Diagrammatically, the relationship between achievement and the dimensions, systematic and intuitive, is depicted with Venn diagrams in Figure 27.

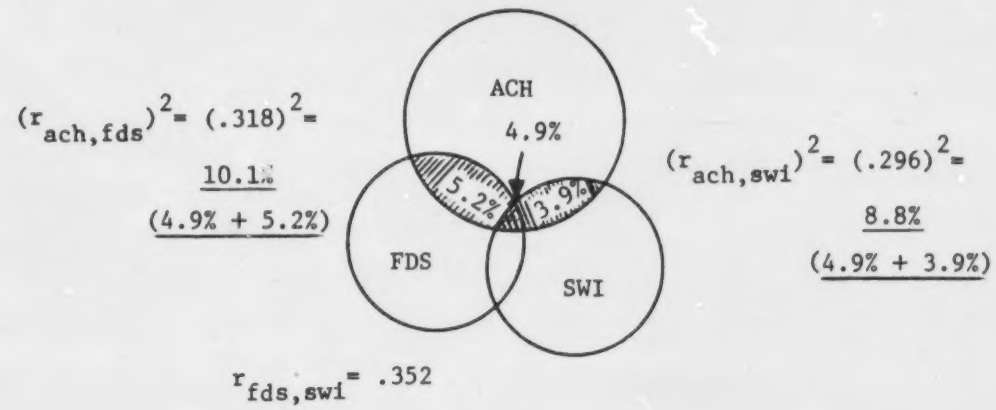


Figure 27. Venn diagram of variance in achievement shared by the systematic and intuitive measures

Hypothesis 3 would be rejected because the cognitive style dimensions, and specifically the systematic and intuitive measures, do have a statistically significant multiple correlation with mathematics achievement.

Regarding the predictive nature of the cognitive style dimensions for mathematics achievement, the total proportion of variance accounted for was only 15.8%. With large samples, as is mandatory in regression analysis, even minute increments in the stepwise regression may be statistically significant. While many dimensions entered the equation

and were statistically significant, a further criteria of meaningfulness must be applied. Extreme reservations should be used in applying the regression prediction equation for the following reasons: (1) relatively low predictive power (.158), (2) a large standard error of estimate (9.25), (3) shrinkage of the multiple correlation (.158 to .119), and (4) instability of the weights from sample to sample.

The analysis for mathematics aptitude is more complex. The multiple correlation coefficient from the regression was .651 using all eight cognitive style dimensions. Significant at the .01 level, this correlation causes rejection of Hypothesis 3 concerning aptitude.

If $R = .651$, then $R^2 = .424$, or 42.4% of variance in aptitude can be accounted for by the cognitive style measures. Using only dimensions that made statistically significant contributions to R^2 in the stepwise regression, R^2 becomes $(.636)^2$ or .404. 40.4% of the variance (of 42.4%) was accounted for by the systematic (FDS), the intuitive (SWI), and the field articulation (GEFT) measures. Zero-order correlations for FDS, SWI, and GEFT with aptitude are .595, .385, and .366 respectively. Percent variance in aptitude attributed to FDS, SWI, and GEFT were respectively 35.4%, 14.8%, and 13.4%. With 40.4% of the variance accounted for by the three measures in conjunction, shared variance exists . . . as in achievement. The intercorrelations among FDS, SWI, and GEFT confirm this finding.

One procedure to "rank order" the importance of the independent variables in accounting for the variability in aptitude is to consider the magnitude of the standardized β weights. "This should be used only if the average correlation among the independent variables is

not large (for example, $\bar{r} \leq .60$), since multi-collinearity in the independent variables results in inaccurate estimation of the regression coefficients (see Kendall, 1961, p. 74)." (Timm, 1975, p. 279)

With an average correlation equal to .316, some consideration can be given the β weights. From the regression equation (a), the respective β weights for FDS, SWI, and GEFT are .471, .195, and .136. Therefore, the systematic measure contributes the most in accounting for explained variance, with the intuitive measure and field articulation measures contributing approximately equal secondary amounts of explained variance in aptitude.

Again, component analysis was used in an attempt to decompose explained variance in aptitude into unique and common variance for each of the three cognitive style dimensions: systematic (FDS), intuitive (SWI), and field articulation (GEFT). The summary is presented in Table 17.

Table 17

Summary of Commonality Analysis
(for Aptitude)

	Dimensions		
	FDS	SWI	GEFT
Unique to FDS	0.176		
Unique to SWI		0.033	
Unique to GEFT			0.026
Common to FDS, SWI	0.072	0.072	
Common to FDS, GEFT	0.065		0.065
Common to SWI, GEFT		0.002	0.002
Common to FDS, SWI, and GEFT	0.041	0.041	0.041
$\sum$:	0.354	0.148	0.134

The unique variance accounted for by the cognitive style dimensions is FDS (17.6%), SWI (3.3%), and GEFT (2.6%). These unique variances are similar to the relative magnitudes of the increases in R^2 from the stepwise regression equation. The commonality analysis does reveal the amount of "overlap" or shared variance for each of the dimensions. Almost half of the 35.4% variance explained by the systematic measure (FDS) is shared with another dimension or dimensions. The unique variance attributed to the intuitive measure (SWI) accounts for 1/5 of the 14.8% variance explained by that measure. The unique variance is relatively low compared to the commonalities; however, the zero-order correlation of SWI with FDS was significant ($\underline{r}$ = .352, $\underline{p} < .001$). SWI was not significantly correlated with GEFT; the commonality among these two measures is only .2 of 1%. The commonality to all three of these three measures (4.1%) could be attributed to the two significant correlations $\underline{r}_{fds,swi}$= .352, $\underline{p} < .001$ and $\underline{r}_{fds,geft}$= .413, $\underline{p} < .001$.

An alternative procedure to explore the specific importance of these three cognitive style measures to aptitude was to compute the regression factor structure coefficients. To obtain these coefficients, the vector of correlations of the predictors with the regression function is divided by the multiple correlation coefficient. An advantage of this interpretative technique is that little emphasis is placed on the magnitude of the β weights. Table 18 provides the structure coefficients for the criterion variable mathematics aptitude.

Table 18

Regression Factor Structure Coefficients

	ANSIE	FDS	GEFT	IPR	MFFT1	MFFT2	SWI	STP
Predicted aptitude	-0.22	1.41	0.86	-0.25	-0.001	-0.40	0.91	-0.08

From Table 18 findings from the multiple regression and from examination of the β weights are confirmed. Of the eight cognitive style dimensions, the cluster of dimensions FDS, SWI, and GEFT have much larger relative coefficients: 1.41, 0.91, and 0.80 respectively.

Interpretation would be that these three measures each make a unique contribution in explaining variance in aptitude, with the ordering of importance: FDS, SWI, and GEFT. Figure 28 depicts the relationship of the cognitive style dimensions: systematic (FDS), intuitive (SWI), and field articulation (GEFT), to an aptitude for mathematics. (In interpretation of Figure 28, each number represents the percent of variance accounted for by its respective simple closed figure. The Figure does not attempt to depict all relative sizes of each of the closed areas in regard to the respective magnitudes of the numbers.)

In combination, FDS, SWI, and GEFT account for 40.4% of the variance in aptitude. FDS (.176 + .072 + .065 + .041) accounts for 35.4% of the variance; 17.6% is unique to the systematic measure. SWI (.033 + .072 + .002 + .041) accounts for 14.8% of the variance; 3.3% is unique to the intuitive measure. GEFT (.026 + .065 + .002 + .041) accounts for 13.4% of the variance; 2.6% is unique to the field articulation measure.

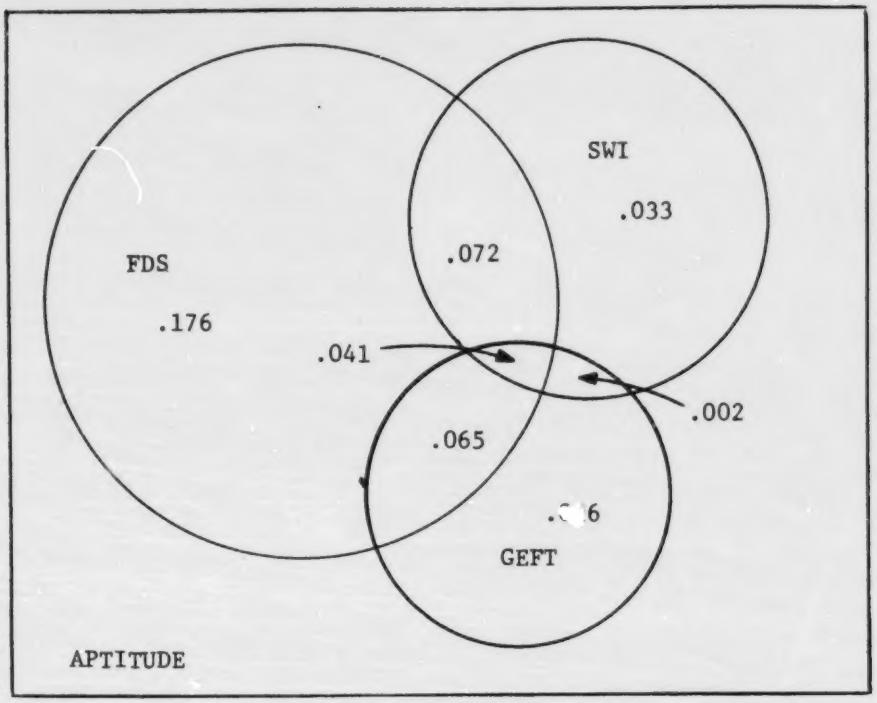


Figure 28. Venn diagram of variance in aptitude shared by the systematic, intutitive, and field articulation measures

Hypothesis 4: Including the measure of intelligence, in addition to the cognitive style dimensions, will not significantly change the multiple correlations in Hypothesis 3.

Analysis. To examine the possible confounding effects of intelligence on the cognitive style dimensions, the following technique was used. After multiple regression equations were derived, the multiple correlation coefficient and the significant "predictors" were analyzed. To remove the effects of intelligence, another set of multiple regression equations was derived; this time intelligence was forced to enter the equation first. This technique has the effect of partialling out the effect of intelligence from all the remaining cognitive style dimensions. The dimensions, other

than intelligence, are reexamined to determine which dimension, if any has the highest partial correlation with the criteria, having partialled intelligence. If the dimension still contributes a statistically significant increase in R^2, then the dimension(s) enters the equation.

Examination of Table 14 (page 117), shows three regression equations for each of the mathematics criteria. Equation (a) is the multiple regression equation containing only the cognitive style dimensions; equation (b) is the regression equation containing both the intelligence measure (APM) and the cognitive style dimensions. APM was forced to enter first with the remaining cognitive style measures entering according to which measure had the highest partial with the mathematics criterion measure. (Equation (c) represents the full model with all cognitive style dimensions entered that still produced a significant multiple R.)

Findings. Hypothesis 4 was rejected because inclusion of the intelligence measure in the regression equations did change the multiple correlation for achievement and for aptitude.

For mathematics achievement, by entering intelligence first, R^2 increased from 14% to 17%. In conjuntion with the increase, the independent variables were reordered (in terms of accounting for variability in achievement). In regression equation (a) the significant independent variables and their β weights were: the systematic measure (.244) and the intuitive measure (.210). When intelligence was forced to enter first, consequently purging the cognitive style dimensions of the effects of intelligence, only the intuitive measure remained. The elimination of the systematic measure is a plausible expectation in that the zero-order correlation between intelligence and the systematic measure

was $r = .521$ ($p < .001$).

To analyze the unique and common variance of the intelligence measure (APM) and the intuitive measure (SWI) with regard to achievement, Table 19 summarizes the commonality analysis.

Table 19

Summary of Commonality Analysis
(for Achievement, with the Intelligence Measure)

	Dimensions	
	APM	SWI
Unique to APM	0.080	
Unique to SWI		0.055
Common to APM and SWI	0.033	0.033
Σ :	0.113	0.088

Of the 11.3% variance in achievement accounted for by APM, only 8% is unique to the intelligence measure; of the 8.8% variance accounted for by SWI, only 5.5% is unique to that measure. A Venn diagram depicts the decomposition of explained variance in achievement in Figure 29.

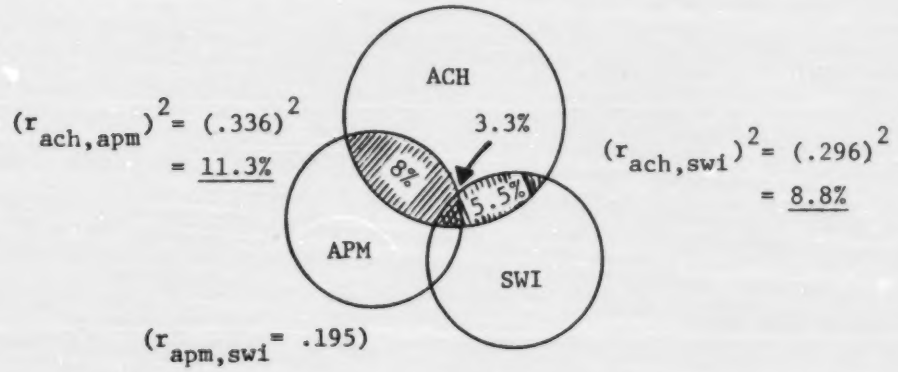


Figure 29. Venn diagram of variance in achievement shared by intelligence and the intuitive measures

In the stepwise regression for achievement--equation (b)--the intelligence measure (APM) contributed 11.3% to $\underline{R}^2$; the intuitive measure (SWI), entering second, contributed a significant increase in $\underline{R}^2$ of 5.5%.

For mathematics aptitude, $\underline{R}^2$ increased only 1% by entering the intelligence measure first. The order of the cognitive style dimensions also remained unchanged. Despite the high zero-order correlation with intelligence, the systematic measure (FDS) remained the first cognitive style dimension to enter the equation. In part, this could be explained by the relatively large β weights for FDS in both equations (a) and (b). Among all of the cognitive style dimensions, the systematic measure (FDS) accounted for 35.4% of the 40.4% explained variance in aptitude in regression equation (a). In regression equation (b), FDS, still having the highest β weight, accounts for 16.8% of a possible 42.2% explained variance; this, after the intelligence measure has been partialled out.

The field articulation dimension (GEFT), highly correlated with intelligence ($\underline{r}$ = .565), contributed no significant increment in $\underline{R}^2$ after APM, FDS, and SWI had been entered; consequently, GEFT was not in equation (b).

The three measures, APM, FDS, and SWI made the following respective increases in $\underline{R}^2$ upon entering the stepwise regression: 22.3%, 16.8%, and 3.4%.

To analyze the unique and common variance components, Table 20 summarizes the commonality analysis. Figure 30 with Venn diagrams illustrates the relationships among the intelligence measure, the cognitive style dimensions, and mathematics aptitude. (In interpretation of Figure 30, each number represents the percent of variance accounted

for by its respective simple closed figure. The figure does not attempt to depict relative sizes of each of the closed areas in regard to the respective magnitudes of the numbers.)

Table 20

Summary of Commonality Analysis
(for Aptitude, with the Intelligence Measure)

	Dimensions		
	APM	FDS	SWI
Unique to APM	0.035		
Unique to FDS		0.112	
Unique to SWI			0.034
Common to APM and FDS	0.129	0.129	
Common to APM and SWI	0.001		0.001
Common to FDS and SWI		0.055	0.055
Common to APM, FDS, and SWI	0.058	0.058	0.058
Σ:	0.223	0.354	0.148

In combination, APM, FDS, and SWI account for 42% of the variance in aptitude. APM (.035 + .129 + .001 + .058) accounts for 22.3% of the variance; 3.5% is unique to the intelligence measure. FDS (.112 + .129 + .055 + .058) accounts for 35.4% of the variance; 11.2% is unique to the systematic measure. SWI (.034 + .055 + .001 + .058) accounts for 14.8% of the variance; 3.4% is unique to the intuitive measure. (See Figure 30.)

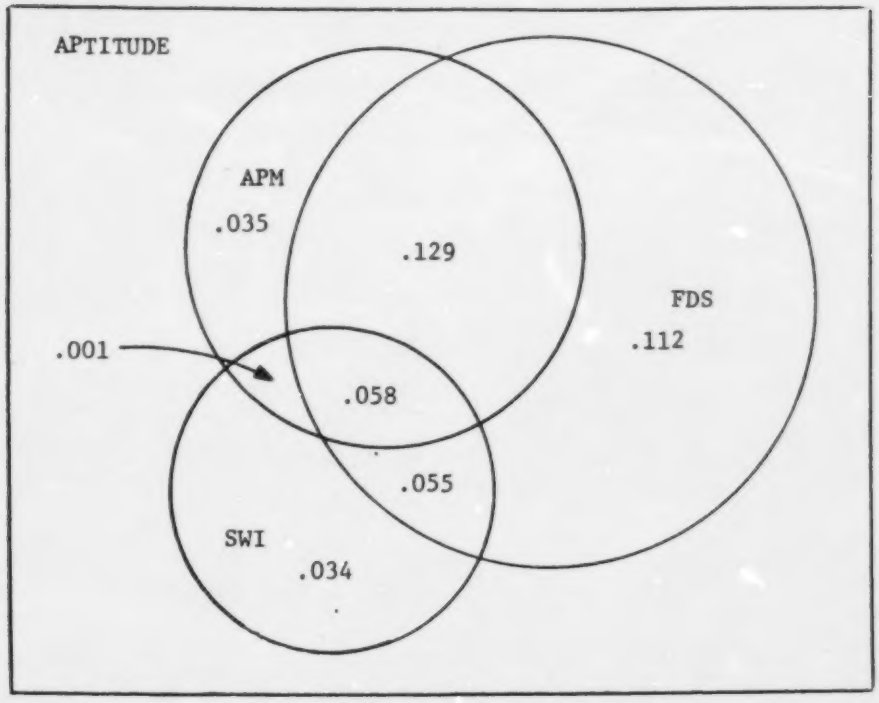


Figure 30. Venn diagram of variance in aptitude shared by intelligence, the systematic and the intuitive measures

The third question cited in the problem statement served to focus attention on the differential nature of the cognitive style dimensions.

> 3) Are cognitive style dimensions differentially exhibited in students in different mathematics sequences of study; and if so, which cognitive style dimensions, separately or combined, significantly discriminate between students in the different mathematics sequences?

To determine possible differences, the variability of scores from the separate cognitive style measures was analyzed using multivariate procedures--appropriate techniques when multiple variates are to be considered in combination, as a system of measurement.

Hypothesis 5. For each of the cognitive style dimensions

(a) field articulation
(b) conceptual tempo

(c) locus of control
(d) preceptive-receptive
(e) intuitive-systematic

there will be no significant difference between groups of students in the different mathematics sequences.

Analysis. A multivariate analysis of variance (MANOVA) served to test Hypothesis 5. A multivariate generalization of univariate analysis of variance, MANOVA ". . . is the study of group differences in location in a multidimensional measurement space. The distinctive multivariate nature of MANOVA designs is that the dependent variable is a vector variable". (Cooley & Lohnes, 1971, p. 224)

The components of the dependent vector variable are the eight measures of the cognitive style dimensions: ANSIE, FDS, GEFT, IPR, MFFT1, MFFT2, STP, and SWI. The groups are the students in the different mathematics sequences of study: ACT, BDP, ELE, GBM, MED, and NUR.

Several approaches for analyzing multivariate data exist. Hummel and Sligo (1971) compared the following three:

(1) do univariate analyses on each of the dependent variables

(2) do a multivariate test on all of the dependent variables, and only if you reject the multivariate null hypothesis, then examine the univariate tests to determine which variables were contributing to the significance

(3) do a multivariate test and if significant, use the simultaneous confidence interval approach of Roy and Bose (1953)

These three approaches are arranged from least control to most control over experiment wise Type I error. Grouping of errors and the generally unknown experiment wise error rates in approach 1 mitigate against its use. The third approach, on the other hand, is such an extremely conservative test that it makes observation of trends

difficult. Coupled with the extreme protection of Type I error--recall from the beginning of the chapter--is a loss of power.

Because approach 2 does provide an overall control of Type I error and its conservatism is not extreme, and because the approach is recommended for its consistency (Hummel & Sligo, 1971, p. 57), this approach was used.

An overall, or multivariate, test (α = .05) was conducted on the dependent vector variables for the six groups. The test in null form was written as:

$$H_o: \begin{bmatrix} u_{11} \\ u_{21} \\ \vdots \\ u_{81} \end{bmatrix} = \begin{bmatrix} u_{12} \\ u_{22} \\ \vdots \\ u_{82} \end{bmatrix} = \ldots = \begin{bmatrix} u_{16} \\ u_{26} \\ \vdots \\ u_{86} \end{bmatrix}$$

Rejection of H_o allowed one to infer that $u_{j1} \neq u_{j2} \neq \ldots \neq u_{j6}$ for at least one of the dependent variables. Univariate analyses of variance were then run on each dependent variable separately. Given the protection against Type I error (overall multivariate and univariate), post hoc comparisons were made to follow up significant univariate tests.

For the dependent variables, when the univariates were significant (α = .05) Tukey's HSD-procedure (α = .05) was used to determine if significant differences existed between the groups on that variable.

Tukey's HSD-procedure was used because according to the schema for making post hoc multiple comparisons (Glass & Stanley, 1976, p. 396), comparisons of interest are exclusively pairwise, all possible comparisons are desired, and group n's are equal. The basic formula is:

$$\hat{\Psi}_{HSD} = {}_{1-\alpha}q_{J,J(n-1)} \sqrt{\frac{MS_w}{n}}$$

where n is the number of observations in any one group, J is the number of sample means, $_{1-\alpha}q_{J,J(n-1)}$ is the percentile point $100(1-\alpha)$ in the Studentized range distribution with df of J and $J(n-1)$, and MS_w is the mean-square within factor levels.

The multivariate test on the dependent vector variables for the six groups was conducted by using the computer packages SAS: PROC GLM (Barr et al., 1976) and MANOVA (Clyde, 1969). SAS provides data on the following test criteria for the hypothesis of no overall effect; Hotelling-Lawley trace (H), Pillai-Bartlett trace (V), Wilks' Lambda criterion (W), and Roy's maximum root criterion (R). All the criteria are functions of $S_e^{-1}S_n$ but significant tests employing these criteria may lead to differing conclusions. In answer to which criteria is best, "there is no unique answer to this question. In a study by Schatzoff (1966), Wilks' Λ-criterion and Hotelling's trace criterion were found to about equally sensitive for a wide spectrum of alternatives, but Roy's largest-root criterion was poor except when the population was such that most of the difference was concentrated in a single dimension." (Tatsuoka, 1971, p. 213, 214)

While V is much more robust for extreme subgroup variance differences, these differences in heteroscedasticity do not occur very often in practice. "For concentrated noncentrality structures with covariance heterogeneity, it is recommended that any of the three statistics (V, T, or W) be used, since the slight robustness advantage V has is offset by the greater power of T and W in these situations." (Stevens, 1979, p. 355)

The oldest and most widely used criterion, Wilks' lambda criterion, was used. Wilks' lambda is defined as the ratio of the two determinants:

$$\Lambda = \frac{|W|}{|T|} \text{ or } \frac{|S_w|}{|S_t|}$$

where W is the with-in groups sums-of-squares-and-cross-products (SSCP) matrix and T is the total SSCP matrix.

The overall multivariate analysis of variance is summarized in Table 21. The matrices for SSCP for between groups, within groups, and total are reported in Appendix G. To test the significance of Wilks' lambda criterion, Rao's F-approximation with p(K-1) and ms-p(K-1)/2 + 1 df were used.

$$\underline{R} = \frac{1 - \Lambda^{1/s}}{\Lambda^{1/s}} \cdot \frac{ms - p(K-1)/2 + 1}{p(K-1)}$$

where $m = N - 1 - (p + K)/2$ and $s = \sqrt{\frac{p^2(K-1)^2 - 4}{p^2 + (K-1)^2 - 5}}$

Findings. With $F^{40}_{730} = 2.74$ ($p < 0.0001$), a significant difference does exist between the six groups on the dependent vector variables. Hypothesis 5 was rejected.

Following the rejection of H_o: $U_1 = U_2 = U_3 = U_4 = U_5 = U_6$, where

$$U_1 = \begin{bmatrix} U_{11} \\ U_{21} \\ \\ U_{61} \end{bmatrix}$$

separate univariates (ANOVA's) were conducted on each dependent variable (the eight cognitive style measures) to provide further insight concerning Hypothesis 5.

Table 21

Multivariate and Univariate Analysis of Variance Summary Table
Group Differences Related to the Cognitive Style Variables

Variable(s)	Test	df	Mean Square	F	p <
ANSIE, FDS, GEFT, IPR MFFT1, MFFT2, SWI, STP	M	40,730		2.74	0.0001**
ANSIE	U	5,174	8.49	0.43	0.8261
FDS	U	5,174	92.26	6.01	0.0001**
GEFT	U	5,174	115.57	5.21	0.0002**
IPR	U	5,174	648.52	2.97	0.0134*
MFFT1	U	5,174	850.95	1.32	0.2569
MFFT2	U	5,174	52.42	1.30	0.2655
SWI	U	5,174	78.14	1.37	0.2362
STP	U	5,174	213.89	4.41	0.0009**

* $p < .05$
** $p < .01$

A model for the separate one-factor analysis of variance, fixed effects, is the general linear model:

$$X_{ij} = \mu + \alpha_j + e_{ij}$$

where X_{ij} is the i^{th} score in the j^{th} group, μ is estimated by the grand mean, α_j is the estimated j^{th} group mean, and e_{ij} is the error term.

The null hypothesis, H_o, and the alternative hypothesis, H_1, are: H_o: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6$; and H_1: "at least two α_j's are different." The α level was set at .05.

To test the hypothesis, mean squares between, MS_b, and mean squares within, MS_w, were computed. The F-ratio MS_b/MS_w was calculated and was

compared to the 100(1 - .05) percentile point in the distribution $F_{J-1,J(n-1)}$. (J = the number of groups, 6; n = the sample size, 180)

$2.21 < {}_{.95}F_{5,174} < 2.29$

SAS: PROC GLM (Barr et al., 1976) provided the statistical computation for the ANOVA's for each of the cognitive style dimensions. Computed F values were compared to ${}_{.95}F_{5,174}$.

The ANOVA's for each of the cognitive style dimensions are summarized in Table 21. The complete ANOVA tables, together with the complete multivariate table, are presented in Appendix H. Means and standard deviations for all variables are presented in Appendix B.

Significant univariate F ratio's were obtained for the cognitive style dimensions: FDS ($F^5_{174} < 6.01$, $p < .0001$); GEFT ($F^5_{174} < 5.21$, $p < .0002$); IPR ($F^5_{174} < 2.97$, $p < .05$); and STP ($F^5_{174} < 4.41$, $p < .0009$).

For each of these four dimensions--the systematic, field articulation, receptive, and preceptive measures--post hoc comparisons were used since the null hypothesis of no group differences in ANOVA had been rejected. Tukey's HSD-procedure was used to isolate the comparisons between means that were responsible for, or contributed to, the rejection of H_o.

Table 22 summarizes the post hoc comparisons for the systematic (FDS) measure. The mean score on FDS for business management students (GBM) was significantly different from that of the accounting students (ACT, $p < .05$), from the data processing students (BDP, $p < .01$), from the electronics students (ELE, $p < .01$), and from the medical laboratory students (MED, $p < .05$). A rank ordering of the means for these five groups would be: BDP, 14.71; ELE, 13.41; ACT, 12.73; MED, 12.52; and GBM, 9.41.

Table 22

Mean Comparison Matrix for the Systematic Measure (FDS)--Post Hoc Analysis

Technological Sequence Means	$\bar{X}_{.ACT}$ (12.73)	$\bar{X}_{.BDP}$ (14.71)	$\bar{X}_{.ELE}$ (13.41)	$\bar{X}_{.GBM}$ (9.41)	$\bar{X}_{.MED}$ (12.52)	$\bar{X}_{.NUR}$ (12.25)	Technological Sequence Means	$\hat{\Psi}$ HSD
		1.98	0.68	3.32*	0.21	0.48	$\bar{X}_{.ACT}$(12.73)	2.883 (.05)
			1.30	5.30**	2.19	2.46	$\bar{X}_{.BDP}$(14.71)	3.403 (.01)
				4.27**	0.89	1.16	$\bar{X}_{.ELE}$(13.41)	
					3.11*	2.84	$\bar{X}_{.GBM}$(9.41)	
						0.27	$\bar{X}_{.MED}$(12.52)	
							$\bar{X}_{.NUR}$(12.25)	

* significant at $p < .05$
** significant at $p < .01$

On the Following Directions test (FDS), the range for all subjects combined was 0.75 to 20.0 with a grand mean of 12.5 and standard deviation equal to 4.2. Figure 31 presents the deviation of each group mean from the total group mean on the cognitive style measure--systematic (FDS).

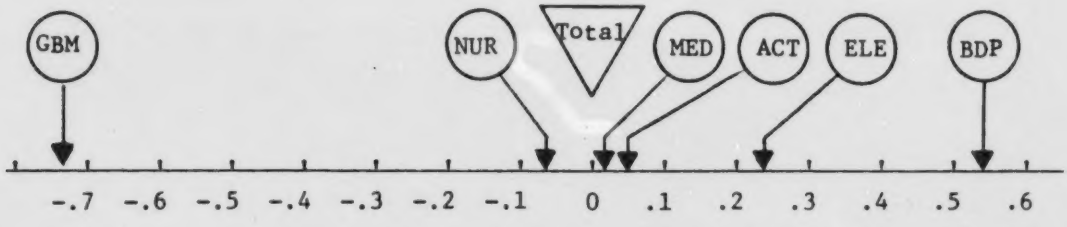


Figure 31. Deviation of group means on the systematic measure (FDS)

Four of the groups had means above the grand mean. A histogram for each group on the systematic measure (FDS) was computed using BMDP7D (Dixon, 1975), and is summarized in Appendix C. Four out of the five groups were statistically more significant on the systematic measure than the business management group (GBM).

Table 23 summarizes the post hoc comparisons for the field articulation measure (GEFT). The business management mean score on GEFT was significantly different from the data processing mean (BDP, $p < .05$) and from the electronic engineering mean (ELE, $p < .01$). Nursing students mean score was also significantly less than both the data processing group mean (BDP, $p < .01$) and the electronic engineering group mean (ELE, $p < .01$). A rank ordering of group means for these four groups would be: ELE, 13.37; BDP, 13.33; GBM, 9.40; and NUR, 8.60.

On the Group Embedded Figures test (GEFT), the range for all subjects combined was 0.0 to 18.0 with a grand mean of 11.1 and a standard deviation equal to 4.98. Figure 32 presents the deviation

Table 23

Mean Comparison Matrix for the Field Articulation Measure (GEFT)--Post Hoc Analysis

Technological Sequence Means	$\bar{X}_{.ACT}$ (11.10)	$\bar{X}_{.BDP}$ (13.33)	$\bar{X}_{.ELE}$ (13.37)	$\bar{X}_{.GBM}$ (9.40)	$\bar{X}_{.MED}$ (11.03)	$\bar{X}_{.NUR}$ (8.60)	Technological Sequence Means	$\hat{\Psi}$ HSD
		2.23	2.27	1.70	0.07	2.50	$\bar{X}_{.ACT}$(11.10)	3.465(.05)
			0.04	3.93*	2.30	4.73**	$\bar{X}_{.BDP}$(13.33)	4.090(.01)
				3.97*	2.34	4.77**	$\bar{X}_{.ELE}$(13.37)	
					1.63	0.80	$\bar{X}_{.GBM}$(9.40)	
						2.43	$\bar{X}_{.MED}$(11.03)	
							$\bar{X}_{.NUR}$(8.60)	

* significant at $p < .05$
** significant at $p < .01$

of each group mean from the total group mean on the cognitive style measure of field articulation (GEFT).

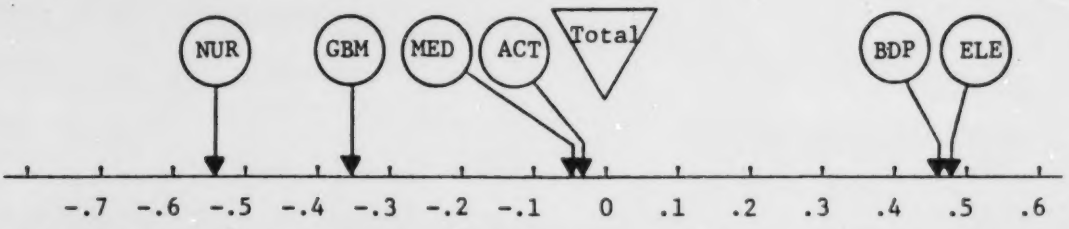


Figure 32. Deviation of group means on the field articulation measure

Four of the groups had means below the grand mean. A histogram for each group on GEFT was computed and is summarized in Appendix C. The electronic engineering (ELE) and the business data processing (BDP) students tend to be more field independent while the business management (GBM) and the nursing (NUR) students tend to be more field dependent--as measured by the Group Embedded Figures test.

Table 24 summarizes the post hoc comparisons for the receptive measure. The medical laboratory mean score (73.57) is significantly different ($p < .01$) from the electronic engineering mean score (59.73).

On the Identical Pictures test (IPR), the range for all groups combined was 28.0 to 96.0 with a grand mean of 66.97 and a standard deviation equal to 15.17. Figure 33 presents the deviation of each group mean from the total group mean on the cognitive style measure receptive (IPR).

A histogram for each group in IPR was computed and is summarized in Appendix C. The medical laboratory students tend to be very receptive; electronic engineering students tend to be least receptive of all six groups.

Table 24

Mean Comparison Matrix for the Receptive Measure (IPR)--Post Hoc Analysis

Technological Sequence Means	$\bar{X}_{.ACT}$ (64.63)	$\bar{X}_{.BDP}$ (67.97)	$\bar{X}_{.ELE}$ (59.73)	$\bar{X}_{.GBM}$ (69.33)	$\bar{X}_{.MED}$ (73.57)	$\bar{X}_{.NUR}$ (66.57)	Technological Sequence Means	$\hat{\Psi}$ HSD
		3.34	4.90	4.70	8.94	1.94	$\bar{X}_{.ACT}$(64.63)	10.867(.05)
			8.24	1.36	5.60	1.40	$\bar{X}_{.BDP}$(67.97)	12.827(.01)
				9.60	13.84**	6.84	$\bar{X}_{.ELE}$(59.73)	
					4.24	2.76	$\bar{X}_{.GBM}$(69.33)	
						7.00	$\bar{X}_{.MED}$(73.57)	
							$\bar{X}_{.NUR}$(66.57)	

** significant at $p < .01$

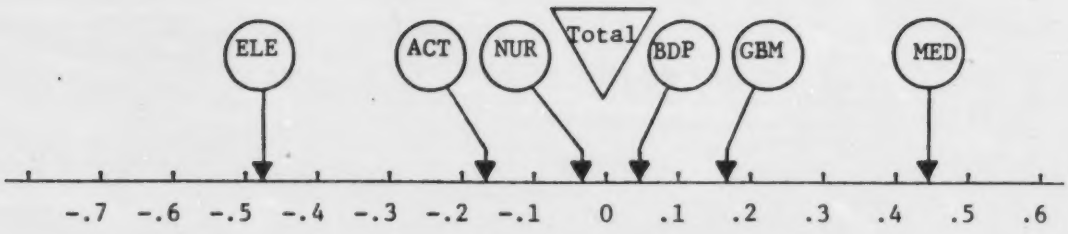


Figure 33. Deviation of group means on the receptive measure

Table 25 summarizes the post hoc comparisons for the preceptive measure. The nursing mean score (27.7) was significantly different ($p < .01$) from the mean scores of both the electronic engineering group (19.03) and the general business management group (21.5). The electronic engineering mean score (ELE) was significantly different ($p < .05$) from that of the accounting (ACT) group (24.97).

A rank ordering of the means of these four groups is: NUR, 27.7; ACT, 24.97; GBM, 21.5; and ELE, 19.03.

On the Symbols test (STP), the range for all groups combined was 8.0 to 48.0 with a grand mean of 22.99 and a standard deviation equal to 7.28. Figure 34 presents the deviation of each group mean from the total group mean on the cognitive style measure preceptive (STP).

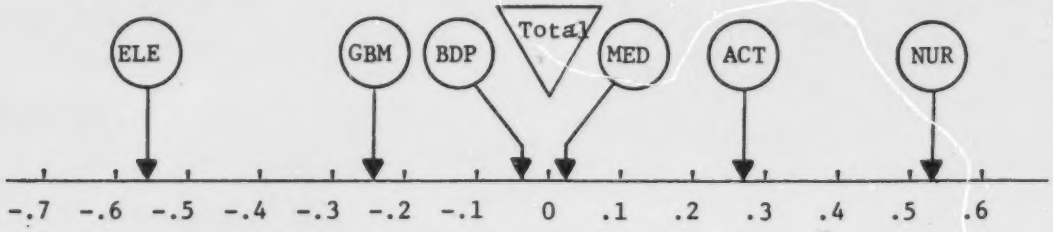


Figure 34. Deviation of group means on the preceptive measure

Table 25

Mean Comparison Matrix for the Preceptive Measure (STP)--Post Hoc Analysis

Technological Sequence Means	$\bar{X}_{.ACT}$ (24.97)	$\bar{X}_{.BDP}$ (22.77)	$\bar{X}_{.ELE}$ (19.03)	$\bar{X}_{.GBM}$ (21.50)	$\bar{X}_{.MED}$ (23.00)	$\bar{X}_{.NUR}$ (27.70)	Technological Sequence Means	$\hat{Y}$ HSD
	2.20	2.20	5.94*	3.47	1.97	2.73	$\bar{X}_{.ACT}$(24.97)	5.121(.05)
			3.74	1.27	0.23	4.93	$\bar{X}_{.BDP}$(22.77)	6.045(.01)
				2.47	3.97	8.67**	$\bar{X}_{.ELE}$(19.03)	
					1.50	6.20**	$\bar{X}_{.GBM}$(21.50)	
						4.70	$\bar{X}_{.MED}$(23.00)	
							$\bar{X}_{.NUR}$(27.70)	

* signficant at $p < .05$
** significant at $p < .01$

A histogram for each group on the preceptive measure (STP) was computed and is summarized in Appendix C. Nursing (NUR) and accounting (ACT) students tend to be more preceptive while general business management (GBM) and electronic engineering (ELE) students tend to be the least preceptive of the six groups.

Hypothesis 6: For each of the cognitive style dimensions

(a) field articulation
(b) conceptual tempo
(c) locus of control
(d) preceptive-receptive
(e) intuitive-systematic

there will be no significant difference between groups of students in the different mathematics sequences, provided intelligence is partialled out.

Analysis. To test Hypothesis 6 regarding group differences on the cognitive style dimensions, with intelligence partialled from the dimensions, discriminant analysis was used. Because discriminant analysis was also used to test Hypothesis 7, a brief description of this technique follows.

Of the two research objectives of discriminant analysis, the analysis aspect, rather than the classification aspect, of the discriminant function was of interest. The "discriminant function" is a linear combination of the form

$$D = \sum_{j=1}^{p} b_j Z_j$$

where D is the score on the discriminant function, the b_j are the weighting coefficients, and the Z_j are the standardized values of the p discriminant variables (the cognitive style measures). The weights

(b_j) are computed in such a way as to maximize separation among the groups (different mathematics sequences).

Since the linear combination could be viewed as a single transformed variable, the F-ratio can be used to test the significance of overall differences among the group means on the transformed variable.

The ratio of the between-group to within-group sums-of-squares of D as a function of the vector of combining weights $\underline{b}$ is:

$$\frac{SS_b(D)}{SS_w(D)} = \frac{\underline{b}'B\,\underline{b}}{\underline{b}'W\,\underline{b}} = \lambda$$

where $\underline{b}' = [b_1, b_2, \ldots, b_p]$, B = between-groups SSCP matrix, and W = the within-group SSCP matrix.

The ratio λ is referred to as the discriminant criterion, which is to be maximized. By calculus of partial differentiation λ is maximized with respect to the unknown weights in vector $\underline{b}$. The resulting vector equation is equivalent to $(B - \lambda W)\,\underline{b} = 0$. The solution to the generalized eigenvalue problem yields the eigenvalues λ_i and the associated eigenvectors of matrix $W^{-1}B$.

In maximizing λ , "several discriminant functions are obtained, the first of which has the largest possible disriminant-criterion value, and each of the others has a conditionally maximal discriminant-criterion value". (Tatsuoka, 1971, p. 162, 163) Each succeeding linear composite of variables, uncorrelated with the existing linear combinations, seeks to additionally maximize group differentiation not accounted for by prior dimensions. The number of possible discriminant functions is equal to the minimum of (K-1, p) where K = the number of groups, p = the number of dependent variables. (Min(K-1, p) is the rank of matrix B.)

The analysis of group differences proceeds in a similar fashion to that used in canonical correlation. First, the significance of the overall difference among the six group centroids was tested using Wilks' Λ criterion. This criterion, then, is also used to determine how many of the discriminant dimensions contribute to group differentiation. Using the relationship that

$$1 / \Lambda = (1 + \lambda_1)(1 + \lambda_2) \ldots (1 + \lambda_m)$$

where λ_i are the obtained eigenvalues,

$$\begin{aligned} V &= -\left[N - 1 - (p + K)/2\right] \ln \Lambda \\ &= \left[N - 1 - (p + K)/2\right] \ln \prod_{i=1}^{m} (1 + \lambda_i) \\ &= \left[N - 1 - (p + K)/2\right] \sum_{i=1}^{m} \ln(1 + \lambda_i) \end{aligned}$$

"V is distributed approximately as a chi-square with $p(K - 1)$ degrees of freedom." (Tatsuoka, 1971, p. 164)

The additive components of V are also each approximately distributed as a chi-square with $p + K - 2i$ degrees of freedom, because of the uncorrelatedness of the successive discriminant functions. To test whether the residual discrimination after removing (or "partialling out") the first discriminant function, etc., are significant, the statistics are summarized from the table in Tatsuoka (1971), p. 165.

Residual after removing	χ^2 - Approximate statistic	Number of degrees of freedom
First disciminant function	$V - V_1$	$p(K-1) - (p+K-2) = (p-1)(K-2)$
First 2 discriminant functions	$V - V_1 - V_2$	$(p-1)(K-2) - (p+K-4) = (p-2)(K-3)$
First 3 discriminant functions	$V - V_1 - V_2 - V_3$	$(p-2)(K-3) - (p+K-6) = (p-3)(K-4)$
⋮	⋮	⋮

"As soon as the residual after removing the first s discriminant functions becomes smaller than the prescribed centile point (that is, the 100(1 - α)th centile) of the approximate chi-square distribution, we may conclude that only the first s discriminant functions are significant at that α level." (Tatsuoka, 1971, p. 165)

Findings. Before any discriminant functions were removed, Wilks' Λ was .5112. Bartlett's V statistic found .5112 to be statistically significant ($p < .0001$); the associated chi-square was 115.418 with $df = p(K - 1) = 40$. This indicates that considerable discriminatory power exists in the cognitive style dimensions and/or the intelligence measure. Those cognitive style dimensions, partialled of intelligence, that contribute most to the discriminatory power are the variables on which the groups will probably differ--these need to be identified.

Analysis. The analysis for Hypothesis 6 proceeds in a fashion analagous to that used in the stepwise multiple regression. With the computer program SPSS: DISCRIMINANT (Nie et al., 1975), a step down procedure served to select cognitive style dimensions and/or the intelligence measure for entry into the analysis on the basis of discriminatory power.

The intelligence measure (APM) was forced to enter the analysis first. Partial multivariate F-ratios are then computed for each of the cognitive style dimensions--not yet entered--to test for the statistical significance of the amount of group centroid separation added--by each of these cognitive style measures--above and beyond the separation produced by APM. The two measures of overall separation of group centroids, based on variables in the equation at this point, are Wilks'

lambda and Rao's **V**. The significance levels are given for the F-approximation of Wilks' lambda and for the amount of change in **V**. This change in **V** has a chi-square distribution so it can be tested for statistical significance. The significance level was set at .05; the stepwise procedure is summarized in Table 26.

Table 26

Summary of Stepwise Discriminant Function Analysis (n = 180)

Step Number	Variable Entered	Wilks' Lambda	Significance	Rao's **V**	Change in Rao's **V**	Significance of Change
1	APM	0.823	0.000	37.468	37.468	0.000
2	STP	0.731	0.000	59.419	21.951	0.001
3	IPR	0.658	0.000	79.452	20.032	0.001
4	GEFT	0.610	0.000	95.061	15.609	0.008
5	MFFT1	0.574	0.000	107.501	12.441	0.029
6	FDS	0.546	0.000	118.099	10.597	0.060*

* not significant at .05 level

Findings. After the intelligence measure was entered, four cognitive style dimensions made significant ($p < .05$) contributions to a change in Rao's **V**: the preceptive measure (STP), the receptive measure (IPR), the field articulation measure (GEFT), and the mean latency on the conceptual tempo measure (MFFT1). The systematic measure (FDS), while not statistically significant ($p \not< .05$), might also be tentatively considered; the remaining unlisted cognitive style dimensions (ANSIE, MFFT2, and SWI) have significance levels greater than .24.

Hypothesis 6 would be rejected since all the dimensions except locus of control and the intuitive measure do significantly contribute to discriminatory power among the six groups. Because of the contribution to group differentiation, these other four dimensions of cognitive style, partialled of the effects of intelligence, reflect differences between groups of students in the mathematics sequences.

Of interest is the change in the order of the cognitive style dimensions that make a contribution to group differentiation as the step down analysis is computed both with and without the intelligence measure.

Without the intelligence measure, the step down analysis is summarized in Table 27.

Table 27

Summary of Stepwise Discriminant Function Analysis Without the Intelligence Measure (APM)

Step Number	Variable Entered	Wilks' Lambda	Significance	Rao's V	Change in Rao's V	Significance of Change
1	FDS	0.853	0.000	30.030	30.030	0.000
2	STP	0.757	0.000	52.166	22.136	0.000
3	GEFT	0.685	0.000	72.415	20.249	0.001
4	IPR	0.626	0.000	89.317	16.902	0.005
5	MFFT1	0.591	0.000	101.128	11.811	0.037

Without the intelligence measure, the first four cognitive style measures to contribute to group differentiation are exactly those dependent variables which were found to have significant univariate

F-ratio's under the MANOVA. The systematic measure (FDS) was correlated (zero-order) .521 ($p < .001$) with intelligence. While FDS contributed the maximum increase to group differentiation without the intelligence measure considered, with the intelligence measure entered, FDS was relegated a much lower (non-significant) rank order.

Hypothesis 7: The profile of cognitive style dimensions will not significantly discriminate between students in different mathematics sequences of study.

A discriminant analysis exclusively of the cognitive style measures was conducted to investigate Hypothesis 7; however in this discriminant analysis, attention was focussed on the discriminant functions, and subsequently, the discriminant function coefficients.

Analysis. As discussed under the analysis for Hypothesis 6, Wilks' Λ criterion is used to determine overall significance among groups and also to determine how many of the discriminant functions contribute--significantly--to group differentiation. Recall that the test statistic for Wilks' Λ , Bartlett's V , is distributed approximately as a chi-square. These test statistics, from SPSS: DISCRIMINANT (Nie et al., 1975), are summarized in Table 28.

Findings. Before any functions were removed, Wilks' Λ was .544 ($p < .001$); this significant lambda indicates considerable discriminatory power exists in the cognitive style dimensions. One significant discriminant function was derived. The second discriminant function was not statistically significant ($p < .05$), but was marginal with a significance level of .059. Thereafter, removal of discriminatory power by successive discriminant functions results in large

Table 28

Significance of Discriminant Functions

Functions Derived	Wilks' Lambda	Chi-square	Degrees of Freedom	Significance
0	0.544	104.707	40	0.000
1	0.709	59.019	28	0.001
2	0.849	28.181	18	0.059
3	0.949	8.946	10	0.537
4	0.989	2.101	4	0.717

non-significant lambdas. The remaining discriminant functions would not be useful to analyze because they would not significantly add to the discriminatory power. However, while not significant, the second discriminant function might be considered for analysis.

Analysis. Two additional measures to judge the importance of the discriminant function(s) are: (1) the relative percentage of the eigenvalue associated with the function, and (2) the associated canonical correlation. Table 29 summarizes these measures.

The sum of the eigenvalues is one measure of the total variance existing in the discriminating variables. An easy reference to the relative importance of a function is the associated eigenvalue expressed as a percentage of the sum of all eigenvalues. The first discriminant function's relative percentage is 45.29; functions two and three also have sizeable percentages--respectively 29.23 and 17.61. An argument might be made, at this point, to analyze the first three discriminant functions.

Table 29

Relative Percentages of Eigenvalues and Canonical Correlations

Discriminant Function	Eigenvalue	Relative Percentage	Canonical Correlation
1	0.304	45.29	0.483
2	0.196	29.23	0.405
3	0.118	17.61	0.325
4	0.041	6.04	0.198
5	0.012	1.83	0.110

The canonical correlations provide a measure of how closely the discriminant functions and the set of (g - 1) dummy group variables are related. High correlations, as in functions 1, 2, and 3, would indicate a function's ability to differentiate between groups. The canonical correlation squared is the proportion of variance in the discriminant functions explained by the groups. In the first three functions, respectively 23.3%, 16.4%, and 10.6% of the variance is accounted for by the groups. The proportion of variance for the last two discriminant functions is less than 5%.

These two measures provide a basis for analyzing at least the first two discriminant functions--despite the marginal non-significance ($p < .05$) of the second discriminant function.

Findings. With the rejection of Hypothesis 7 because the profile of cognitive style dimensions does provide a significant discriminant function for differentiation of students in the six mathematics sequences of study, further insight is gained by supplemental analysis. Because

the discriminant functions can be thought of as axes of a geometric space, the use of two discriminant functions allows a spatial (two dimensional) representation of the relationship among the groups.

The means of the two discriminant functions for the six groups are reported in Table 30, and the group centroids are plotted in Figure 35.

Table 30

Discriminant Function Means

Group	Function 1	Function 2
ACT	0.08	0.36
BDP	-0.35	0.20
ELE	-0.87	-0.07
GBM	0.28	-0.78
MED	0.29	-0.15
NUR	0.58	0.43

The graph in Figure 35 shows that the first discriminant function separates the six groups ranging from a low of -0.87 to a high of 0.58; the rank order is: ELE, BDP, ACT, GBM, MED, and NUR. The second function separates ELE, MED, and GBM from the other three groups; GBM is relatively far from all other five groups. Rank order by the second function is: GBM, MED, ELE, BDP, ACT, and NUR.

Analysis. To measure the extent of differentiation, other than shown by graphical or statistical significance,

$$\hat{\omega}^2_{\text{mult}} = 1 - \frac{N}{(N - K)(1 + \lambda_1)(1 + \lambda_2) + 1}$$

was adapted from Tatsuoka, 1970, p. 48, for two discriminant functions.

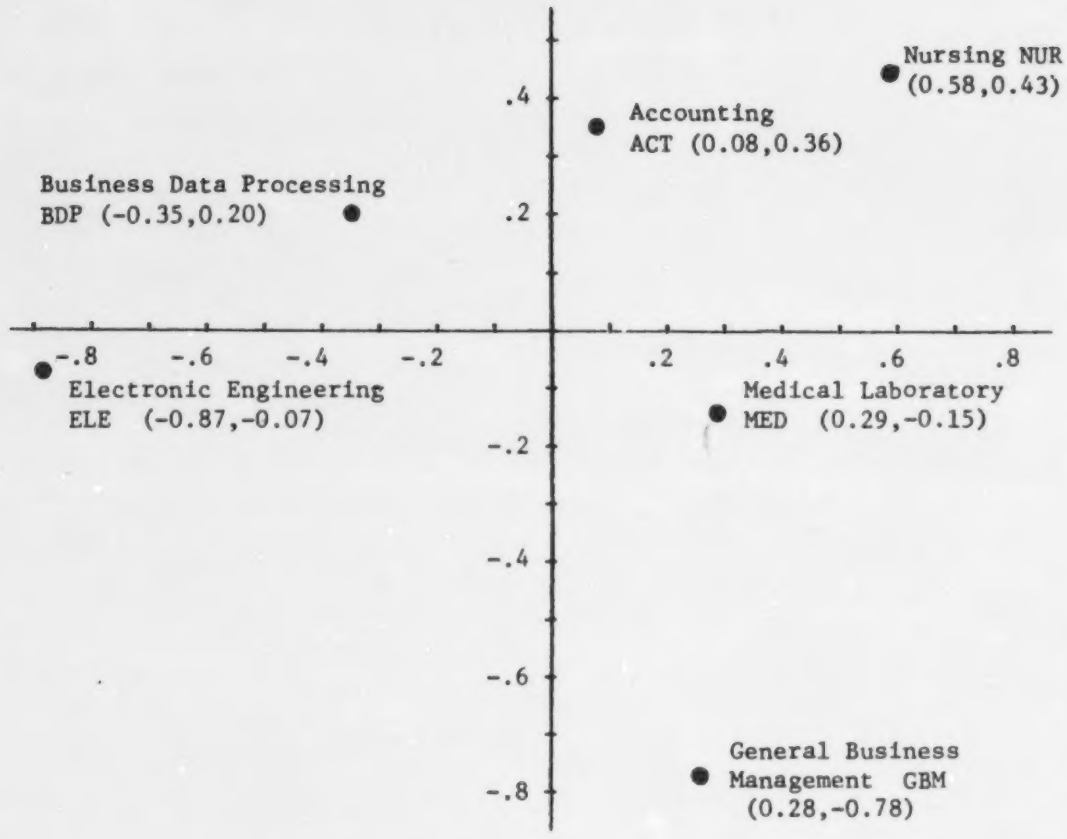


Figure 35. The six group centroids in discriminant-function space

This statistic provides an estimate of total discriminatory power and is the multivariate analogue to the "estimated ω^2 " in ANOVA.

$$\hat{\omega}^2_{mult} = 1 - \frac{180}{(180 - 6)(1 + .304)(1 + .196) + 1}$$

$$= 0.338$$

Thus, about 33.8% of the total variability of the two discriminant functions is attributable to group differences, or 33.8% of the variability in the discriminant space is relevant to group differentiation.

Using 33.8% as a measure of the total discriminatory power residing in the discriminant functions, and having plotted the configuration of centroids, the discriminant function coefficients were then examined to see if some meaningful interpretation could be given to the two discriminant functions obtained.

To investigate the relative discriminatory power of each cognitive style measure, the two discriminant functions' weightings were analyzed. Because multiple discriminant analysis can be computed as a special case of canonical regression, two techniques used earlier to interpret the canonical variate weights and the multiple regression weights are also used here to interpret the discriminant function weights. Examination of the standardized discriminant function coefficients will be supplemented by examination of the structure coefficients (discriminant function-variable correlations).

Table 31 reports the standardized discriminant function coefficients for the cognitive style dimensions for the two discriminant functions.

Table 31

Standardized Discriminant Function Coefficients

Dimension	Function 1	Function 2
ANSIE	0.038	-0.105
FDS	-0.272	0.653
GEFT	-0.639	-0.174
IPR	0.330	-0.473
MFFT1	0.328	-0.152
MFFT2	-0.110	-0.263
SWI	0.210	0.116
STP	0.415	0.715

Cognitive style dimensions are examined if their weights (coefficients) have absolute values no less than one-half the largest weight. (This practice is used by Tatsuoka; another guideline, suggested by Barcikowski and Stevens (1975) is to examine only those weights $\geq$ .30 or .40.)

Findings. For discriminant function one, the cognitive sytle measures that contribute most are field articulation (GEFT, in a negative direction), and the preceptive measure (STP, in a positive direction). A person with a high score on this function tends to be field dependent (use of a more global undifferentiated approach to the perceptual process) and tends to be preceptive (use of concepts and categories to code data with attempts to fit new learning to precepts). While nursing students (NUR) would represent this end of the continuum, electronic engineering (ELE) and data processing (BDP) students would represent the other extreme. Field independent and non-preceptive individuals would tend to use a more analytical, differentiated approach to learning, with sensitivity to the stimulus itself.

For discriminant function two, the weights with the largest absolute magnitudes are those for STP (.715), FDS (.653), and IPR (-.473). A person with a high score on this function tends to be preceptive (fits learning to precepts), systematic (methodical; approach problems by planning), and non-receptive (attention to relations rather than focus on detail). Nursing (NUR) and accounting (ACT) groups cluster in this direction, while general business management (GBM) tend to represent the other end of the continuum on this discriminant function.

Caution should be given to interpretation of the weightings in part because of the relatively low discriminatory power of the two discriminant functions (33.8%). As part of the discriminant function analysis, the following percents of groups were "classified" correctly by the discriminant functions: ACT (16.7%), BDP (40.0%), ELE (56.7%), GBM (50.0%), MED (36.7%), NUR (40.0%); and the "group" as a composite (40.0%).

To supplement the discussion and possibly support prior findings, the structure coefficients are presented in Table 32.

Table 32

Structure Coefficients--Cognitive Style Measures and Discriminant Scores

Scores	ANSIE	FDS	GEFT	IPR	MFFT1	MFFT2	SWI	STP
Disc. Fct. 1	0.05	-0.44	-0.68	0.39	0.30	-0.10	-0.07	0.54
Disc. Fct. 2	-0.13	0.67	0.12	-0.21	0.06	-0.27	0.33	0.52

The interpretation of function one weights would be substantiated based on the structure coefficients. However, in the analysis of function two, intercorrelations among cognitive style measures have produced a change in the third measure. The receptive measure (IPR) is no longer ranked third, the intuitive measure is (SWI).

With the standardized coefficients, a variable may show a relatively low ranking on the discriminant functions--especially if that variable is correlated with a much higher ranking measure.

This is exemplified by the intuitive measure. SWI significantly correlated with the systematic measure (FDS, $p < .001$); and after FDS was partialled from SWI, SWI's relative importance to the function appeared less. With the structure coefficients, each variable's rank represents its "pair-wise" contribution to the discriminant function. (This provides a good example for the use of both standardized and structure coefficients in interpretation of discriminant function weights.)

In light of the structure coefficients, a person who scores high on discriminant function two, tends to be preceptive and systematic--as before--and possibly somewhat intuitive (relatively low coefficient).

A summary of the study, conclusions, interpretation of analyses and findings, together with recommendation for future research on cognitive style--as related to mathematics education--are presented in Chapter V.

CHAPTER V

Summary of the Study

The purposes were: (1) to investigate the relationship between cognitive style and the learning of mathematics at the two-year college level, and (2) to examine the influence of the cognitive style dimensions, not only in isolation, but in interaction with each other, as they relate to the learning of mathematics. Specifically, the cognitive style measures that were derived from the dimensions: conceptual tempo, field articulation, locus of control, and the McKenney model, were analyzed with regard to mathematics achievement, aptitude for mathematics, and attitudes toward mathematics. Research efforts focused on the analysis of the correlative, predictive, and differential nature of the selected cognitive style dimensions.

The following eleven assessment instruments were used:

Construct Measured	Assessment Instrument	(Acronym)
Conceptual tempo	Matching Familiar Figures Test	
latency to first response		(MFFT1)
total number of errors		(MFFT2)
Field articulation	Group Embedded Figures Test	(GEFT)
Locus of control	Adult Nowicki-Strickland Internal External Scale	(ANSIE)
McKenney model		
information gathering		
preceptive	Symbols Test	(STP)
receptive	Identical Pictures	(IPR)

Construct Measured	Assessment Instrument	(Acronym)
information evaluation systematic intuitive	Following Directions Scrambled Words	(FDS) (SWI)
Mathematics achievement	Columbus Technical Institute Mathematics Placement Tests	(ACH)
Aptitude for mathematics	Mathematics Aptitude Test	(APT)
Attitude toward mathematics	Revised Math Attitude Scale	(ATT)

From a review of the literature, twenty questions were generated for investigating cognitive style. By conducting a pilot study, the questions were narrowed to three for investigation, and further scrutiny was made of both the cognitive style dimensions and their respective assessment instruments.

To provide insight into the questions for investigation, seven testable hypotheses were formulated and listed under the three areas: the correlational nature, the predictive nature, and the differential nature of cognitive style dimensions.

To test the hypotheses, data was collected spring quarter, 1979, from a sample of 180 students enrolled at Columbus Technical Institute, the largest two-year technical college in Ohio. From each of six different sequences of mathematical study, 30 students were selected at random. During an eleven week period, each subject was administered eleven assessment instruments. The order of the assessment instruments was randomly determined for each testing session, the measures were administered in groups of not more than 15 subjects, and each subject completed the instruments within four testing sessions.

After coding and editing, the data was analyzed using five sub-analyses: (1) Pearson product moment intercorrelations of all variables; (2) canonical correlational analysis between the set of cognitive style measures and the mathematics criterion variables; (3) multiple correlational analysis with the independent variables the cognitive style dimensions and the dependent variables, in turn, mathematics achievement, aptitude, and attitudes; (4) multivariate analysis of variance with the cognitive style dimensions as the independent variables; and (5) discriminant analysis with the cognitive style dimensions as the discriminating variables and sequences of mathematical study serving to define subgroups.

Observations and findings, warranted on the basis of analyzing the data, are summarized under each hypothesis.

Hypothesis 1: None of the following variables will exhibit first order correlations with any of the others in a significant manner:

The student's position on each cognitive style dimension:

(a) field articulation as measured by the Group Embedded Figures Test
(b) conceptual tempo as measured by the Matching Familiar Figures Test
(c) locus of control as measured by the Adult Nowicki-Strickland Internal External Scale
(d) preceptive-receptive as measured by the Symbols Test and Identical Pictures
(e) intuitive-systematic as measured by Scrambled Words and the Following Directions test

and the student's:

(f) grade in the first required mathematics course
(g) mathematics achievement as measured by the Columbus Technical Institute Mathematics Placement Tests
(h) aptitude for mathematics as measured by the Mathematics Aptitude Test
(i) attitude toward mathematics as measured by the Revised Math Attitude Scale
(j) measure of intelligence as determined by Advanced Progressive Matrices.

Significant bivariate correlations ($p < .001$) are organized under four areas: (1) correlations among the cognitive style dimensions, (2) correlations between the cognitive style dimensions and the mathematics criterion variables, (3) correlations among the mathematics criterion measures, and (4) research variables correlated with the intelligence measure.

(1) The systematic measure (FDS) correlated with both the field articulation measure (GEFT) and the intuitive measure (SWI). The preceptive (STP) and the receptive (IPR) measures--components of McKenney's information gathering model--were correlated. The measures of conceptual tempo (MFFT1 and MFFT2) were negatively correlated.

(2) Mathematics achievement correlated with the following cognitive style measures: the systematic measure (FDS), and the intuitive measure (SWI). Aptitude for mathematics correlated with these cognitive style measures: the systematic measure (FDS), the intuitive measure (SWI), and the field articulation measure (GEFT).

(3) Intercorrelations among the mathematics criterion variables included: achievement (ACH) was correlated with aptitude for mathematics (APT), with attitudes toward mathematics (ATT) and with high school mathematics product index (HSMPI). Aptitude for mathematics (APT) and attitudes toward mathematics (ATT) were also correlated with high school mathematics product index (HSMPI).

(4) The intelligence measure (APM) had the following significant correlates: grade point average (CTIGPA); the three cognitive style measures (the systematic measure--FDS, the field articulation measure--GEFT, and one of the conceptual tempo measures--MFFT2); and the

mathematics criterion variables achievement (ACH) and aptitude (APT)

Hypothesis 2: The subset of scores from the cognitive style dimensions will not exhibit a significant canonical correlation with the subset of scores from mathematics achievement, aptitude, and attitudes.

A significant canonical correlation existed between the set of cognitive style dimensions and the set of mathematics criterion measures. The scores from the systematic measure (FDS), the intuitive measure (SWI) and the field articulation measure (GEFT) from set one and the scores from aptitude and achievement from set two contributed most to the canonical correlation of .661 ($p < .001$).

Hypothesis 3: None of the cognitive style dimensions will make a significant contribution to the multiple correlation with:

(a) mathematics achievement
(b) aptitude for mathematics
(c) attitudes toward mathematics

From the multiple correlation with mathematics achievement both of the cognitive style dimensions FDS and SWI made a significant contribution. For the criterion aptitude for mathematics, each of the dimensions FDS, SWI, and GEFT significantly contributed to the multiple correlation. None of the cognitive style measures contributed significantly to the multiple correlation with attitudes toward mathematics.

Hypothesis 4: Including the measure of intelligence, in addition to the cognitive style dimensions, will not significantly change the multiple correlations in Hypothesis 3.

Including a measure of intelligence did significantly change the multiple correlation that was obtained solely with the cognitive style dimensions. The multiple correlation of the cognitive style measures with achievement increased from .374 to .412 with the addition of the

intelligence measure. However, FDS did not remain a significant contributor. SWI was the most important cognitive style measure contributing to the multiple correlation.

The multiple correlation of the cognitive style measures with aptitude increased from .640 to .648 with the intelligence measure added. The rank order of the cognitive style dimensions did not change. After the intelligence measure was partialled from all cognitive style dimensions, FDS and SWI continued to make significant contributions to the multiple R with mathematics aptitude. The contribution of the field articulation measure (GEFT) was no longer significant.

The multiple R with attitude toward mathematics was not significantly changed by including the measure of intelligence with the cognitive style dimensions.

Hypothesis 5: For each of the cognitive style dimensions

(a) field articulation
(b) conceptual tempo
(c) locus of control
(d) preceptive-receptive
(e) intuitive-systematic

there will be no significant difference between groups of students in the different mathematics sequences.

Differences were investigated between groups of students from six different sequences of study: accounting (ACT), business data processing (BDP), electronic engineering (ELE), general business management (GBM), medical laboratory (MED), and nursing (NUR).

An overall multivariate effect existed between the six groups of students on the set of cognitive style measures. Significant ANOVA's were reported for four cognitive style dimensions: the systematic

measure, field articulation, the receptive measure, and the preceptive measure.

For the systematic, the GBM group tended to be the least systematic and was significantly different from the following groups: BDP, ELE, ACT, and MED.

For the field articulation measure, both the GBM and NUR groups tended toward field dependence and both were significantly different from the ELE and BDP groups, who tended to be more field independent.

For the receptive measure, the MED group was most receptive, ELE least receptive, and the two groups were significantly different.

For the preceptive measure, the NUR group tended to be most preceptive and was significantly different from the groups GBM and ELE. The ELE group, the least preceptive, was significantly different from both the NUR and ACT groups.

Hypothesis 6: For each of the cognitive style dimensions

(a) field articulation
(b) conceptual tempo
(c) locus of control
(d) preceptive-receptive
(e) intuitive-systematic

there will be no significant difference between groups of students in the different mathematics sequences, provided intelligence is partialled out.

With the cognitive style dimensions partialled of intelligence four dimensions significantly were able to contribute to group differentiation: STP, IPR, GEFT, and MFFT1.

Group differences are associated with the following cognitive style dimensions: the preceptive measure, the receptive measure, field articulation, and mean latency on the conceptual tempo measure.

The systematic measure, the best contributor to group differentiation under Hypothesis 5, is relegated a lesser role after being purged of the effects of intelligence.

Hypothesis 7: The profile of cognitive style dimensions will not significantly discriminate between students in different mathematics sequences of study.

The profile of cognitive style dimensions combined into a discriminant function that does differentiate students in the six sequences of mathematical study. The dimensions that contribute most to the discriminant function are field articulation and the preceptive measure. The preceptive, systematic, and receptive measures contribute to the discriminatory power in a second, marginally non-significant discriminant function.

Conclusions and Interpretations

In Chapter I, a statement was quoted from Frederick & Klausmeier: "Differences among learners in styles of perceiving, cognizing, and conceptualizing are probably as real as are differences in general intellectual ability and educational achievement". (1970, p. 668) Cognitive style appears to be related to learning mathematics at the two-year college level. Of the eight cognitive style dimensions investigated three were related to the mathematics criterion variables (achievement and aptitude) in the correlative and predictive phases of the study. Three other dimensions were influential in the phase that examined the differential role played by cognitive style.

Since this is an exploratory study that relies heavily upon correlational techniques, caution must be exercised not to imply causal

relationships, nor to extrapolate interpretations of findings beyond the scope of the cognitive style constructs, as assessed herein. In this context, the following specific conclusions are offered for the three investigative questions that were posed in the problem statement.

Question 1. Is there a significant correlational relationship between subsets of scores from student's cognitive style dimensions and subsets of scores from their achievement in mathematics, aptitude for mathematics, and attitudes toward mathematics?

The cognitive style dimensions: systematic (FDS), intuitive (SWI) and field articulation (GEFT) are correlationally related to both mathematics achievement and aptitude. Interpretation of a significant canonical correlation ($r = .661$, $p < .001$) and the canonical variates would be that students characterized as systematic, intuitive, and field independent, as defined in this study, tend to have a higher aptitude for mathematics and tend to be higher achievers in mathematics.

The correlations of the cognitive style dimensions with each mathematics criterion variable are examined separately. Of the 14% of variance in achievement accounted for by the cognitive style dimensions, 5.2% is unique to the systematic measure and 3.9% is unique to the intuitive measure; the remaining 4.9% is variance shared by FDS and SWI.

To investigate the specific nature of the systematic and intuitive constructs, a multiple R was computed with intelligence partialled from the cognitive style dimensions. The systematic measure made no significant contributions to the multiple correlation provided intelligence was partialled. The systematic measure seems to be related to, or composed of, a general reasoning or intelligence factor. The zero-order correlation between the systematic measure and intelligence was .521 ($p < .001$).

The intuitive measure was the sole cognitive style dimension to contribute to the multiple correlation with mathematics achievement, accounting for 8.8% of the variance. The variance common to both intuitive and intelligence was 3.3%, therefore, only 5.5% of variance was unique to the intuitive measure.

For achievement in mathematics, both the R^2 for the cognitive style dimensions, and the R^2 for the cognitive style dimensions partialled of intelligence, were statistically significant. However, further substantive interpretation was not made because of the fairly low multiple correlations (R = .374, and R = .297 with intelligence partialled). Meaningful interpretations would be questionable.

Possible reasons for the low correlations might be: (a) no meaningful relationship between the cognitive style dimensions and mathematics achievement, (b) lack of an extremely valid, highly reliable standard measure of achievement (the college's mathematics placement tests for each of the technologies were used to assess achievement), or (c) lack of research control over the testing of achievement (the achievement test was one of three tests completed on student's home time).

For the variance in aptitude for mathematics, the multiple correlation between the cognitive style dimensions and aptitude was .636; or, $(.636)^2$ = 40.4% of the variance in aptitude was accounted for by the cognitive style measures. The significant contributors to the multiple R were the systematic dimension (FDS), the intuitive dimension (SWI), and field articulation (GEFT) with unique variances of 17.6%, 3.3%, and 2.6% respectively. Variance in aptitude common to both FDS

and SWI was 7.2%, common to both FDS and GEFT was 6.5% and common to FDS, SWI, and GEFT was 4.1%.

With the cognitive style dimensions partialled of intelligence, the systematic and intuitive measures remained significant contributors to the multiple R with unique variances of 11.2% and 3.4% respectively. For achievement, the systematic measure made no significant contribution provided intelligence was partialled, yet for aptitude systematic continues to significantly contribute to the multiple R. Field articulation--highly correlated with intelligence ($r = .565$, $p < .001$)--contributed no significant increment in R^2 beyond the systematic and intuitive measures.

Because of the relationship of the cognitive style dimensions (systematic, intuitive, and field articulation) to achievement and aptitude, a closer scrutiny of these measures was made. Besides possibly providing some unifying research for these dimensions, substantive findings for the McKenney model dimensions would contribute to the model's almost non-existent research base.

The possibility of an underlying construct for FDS, SWI, GEFT, and aptitude, perhaps related to intelligence, seemed conceivable. Both FDS and GEFT are significantly correlated with intelligence, and SWI is in turn significantly correlated with FDS. With intelligence partialled from the cognitive style dimensions, as in the analysis for Hypothesis 4, some cognitive style dimensions remained significant correlates (in the multiple correlational sense) with achievement (SWI) and aptitude (FDS, SWI); some dimensions were influenced by the partialling of intelligence.

For achievement (assessed by non-verbal mathematics problems) with intelligence partialled, FDS no longer remains the principal contributor to the multiple R. SWI becomes the primary contributor. The Following Directions test, to measure systematic (FDS) is a rather difficult verbal oriented instrument, significantly correlated with the intelligence measure ($r = .521$, $p < .001$).

McKenney's use of Following Directions is to measure the construct systematic (systematic individuals tend to approach a problem by devising a method with specific, sequential steps to solution). The Educational Testing Service claims the test assesses integrative processes (the ability to keep in mind simultaneous conditions or to continue several conditions, premises, or rules in order to produce a correct response).

The possibility exists that different levels of cognitive functioning could be involved here. For the achievement test, only the lower levels of Bloom's taxonomy (1964) are required for a high performance. For example, the mathematics placement test for the nursing group is an easy test, requiring not much more than knowledge, some comprehension, and maybe some application. Success could even be largely attributed to memory.

However, for the Following Directions test, higher levels of intellectual ability are necessary for success (i.e. analysis); in addition the Following Directions test is verbal oriented. Verbal ability plays a very limited role in solving mathematical problems on the achievement test. Possibly the Following Directions test is a verbal measure of intelligence. The APM, a non-verbal measure of

intelligence, also requires intellectual functioning at higher levels of Bloom's taxonomy.

The Scrambled Words test, to measure the intuitive dimension, is not significantly correlated with intelligence, yet remains the principal contributor to accounting for explained variance in achievement. According to the McKenney model, this test measures the construct intuitiveness (an intuitive individual more often considers trial-and-error, defining or redefining the problem, moving back and forth to a solution). On the achievement test, an "average" memory with high "intuitive" skills could produce success.

An examination of the cognitive style dimensions that are related to aptitude further supports the aforementioned explanations. The systematic measure (FDS), intuitive measure (SWI), and field articulation (GEFT) all significantly contribute to the multiple R for mathematical aptitude. Both FDS and APT are assessed by rather difficult verbal-oriented instruments, and both have a significant high zero-order correlation ($r = .595$, $p < .001$). These two may share an underlying construct of verbal ability or a verbal related intelligence factor.

GEFT and the intelligence factor are both assessed by non-verbal figural instruments, and their bivariate correlation is .565 ($p < .001$). After intelligence (assessed by a non-verbal figural instrument) is partialled from the cognitive style dimensions, FDS (verbal assessment) remains a significant contributor to the multiple R with aptitude, yet GEFT (non-verbal figural assessment) no longer remains a significant contributor.

The remaining cognitive style dimension , intuitive, measured by the Scrambled Words test, significantly contributes to explained variance in aptitude both before and after partialling out intelligence (non-verbal). Not being significantly correlated with intelligence might explain the dimension's insusceptibility to change. In addition, a high performance on the Scrambled Words test could easily be associated with a high verbal ability. The correlation between FDS (verbal) and the intuitive measure might also signal an underlying construct related to verbal ability.

In conclusion, one could also not exclude the possibility that some of the relationship of the intuitive dimension to mathematical aptitude might be due to the construct as purported by McKenney. Because the aptitude test was a multiple choice test, an "intuitive" individual might have obtained correct answers by a "trial-and-error, defining or redefining, and elimination" type of cognitive functioning.

Of all eight cognitive style measures investigated, none significantly correlated with attitudes toward mathematics. Viewed as feelings, and predispositions, . . . attitudes may be somewhat removed from perception and/or cognition. While attitudes may indeed influence perception or cognition, they did not seem closely related to the cognitive style dimensions studied here. Other possibilities that may exist for the apparent non-relationship might include: (a) no relationship exists between cognitive style (self consistent and characteristic modes of perceptual organization and conceptual categorization) and attitude (learned predisposition or tendency . . . to respond positively or negatively); (b) the Revised Math Attitude

Scale, used to assess attitude, was one of the three tests completed on student's home time; and (c) for the different groups investigated, the range for what is meant by "attitude toward mathematics" (referent) might have been too diverse.

Statistical Power:

Be design, Type II error (β) was given considerable thought because general patterns and/or relationships were sought in this exploratory study; failure to reject a null hypothesis might obscure a potential area for future research. For the correlational phase of the study--to investigate question one--liberal α levels (.10) and large sample size (180) were chosen to secure more statistical power ($1 - \beta$). (A "family confidence level" < .10 provided a "statement confidence level" < .001. These α levels provided power $\geq$ .95--for example--for analyzing the 15 by 15 correlation matrix under Hypothesis 1.

In the rejection, then, of Hypothesis 1, 31 out of 105 correlations were statistically significant (statistically significant from $r_{xy} = 0$). However, in the analysis of the remaining 74 non-significant correlations (including several non-significant correlates with the criterion measures of mathematics achievement and attitudes toward mathematics) the design of the research (α < .001, power $\geq$ .95) indicated adequate power has been provided and the probability of committing a Type II error was slight ($\beta \leq .05$).

Question 2: Which cognitive style dimensions, separately or combined, are significant predictors of (a) achievement in mathematics, (b) aptitude for mathematics, and (c) attitudes toward mathematics?

Multiple regressions were used for analyzing Hypotheses 3 and 4, to evaluate the contribution of specific variables, both controlling and not controlling for the confounding variable intelligence, and to find relations and/or explanations for the seemingly complex multivariate relationships. Although the word "predictors" is used, the focus of investigating the predictive nature was to evaluate and measure the overall dependence (regression) of each of the variables (achievement, aptitude, and attitudes) on the set of cognitive style dimensions. The intent was not solely on finding the best linear prediction equation and evaluating its predictive accuracy--the practical application of prediction, per se, was a secondary and subsequent outcome of using the regression analysis for explanation.

For mathematics achievement, the cognitive style dimensions offer little in the way of prediction. With all eight dimensions entered into the prediction equation, only 15.8% of the total variance was accounted for. However, by retaining just those dimensions that provide statistically significant contributions to R^2, only systematic and intuitive dimensions are present--accounting for 14% of the total variance.

Practical applications of the prediction equation would not be suggested for the following reasons: (1) relatively low predictive power (.158, full model), (2) a large standard error of estimate (9.25), (3) shrinkage of the multiple correlation (.158 to .119), (4) instability of the beta weights (determine the relative importance of dimension contribution, and (5) relative lack of meaningfulness of the dimensions retained--especially in light of the confounding variable intelligence.

Attention should also be directed to one of the most probable causes for the low predictive power; achievement was measured by using different achievement subtests and then standardizing each test with a mean of 50 and standard deviation of 10.

The cognitive style dimensions in the full model account for 42% of the total variance in aptitude for mathematics. Retaining only statistically significant contributors to the R^2, the systematic, intuitive, and field articulation measures account for 41%. Partialling out intelligence, the systematic and intuitive measures significantly contribute to R^2.

The prediction equation has fairly good predictive power with a moderate standard error of estimate = .354, ($0 < .354 < .455$). The estimate shrinkage of the multiple correlation is minimal (.41 to .38).

However, before practical application of the prediction equation for mathematical aptitude, several suggestions would be offered: (1) either a replication of the present study or a cross-validation should be performed, and (2) the homogeneity of the population should be studied. From the analysis of Hypotheses 5, 6, and 7, discriminant analysis showed the six groups in this study were significantly different; this heterogeneity has an effect of decreasing the multiple correlation, hence the predictive power.

Question 3. Are cognitive style dimensions differentially exhibited in students in different sequences of mathematical study; and, if so, which cognitive style dimensions, separately or combined, significantly discriminate between students in the different mathematics sequences?

A multivariate analysis of variance, supplemented by the "discrimination aspect" of discriminant analysis provided findings

regarding the study of group separation--differences--with respect to the cognitive style dimensions and to the (discriminator) variable contributions to separation.

The cognitive style dimensions: systematic (FDS), preceptive (STP), field articulation (GEFT), and receptive (IPR) are differentially exhibited in the students in the different sequences of study.

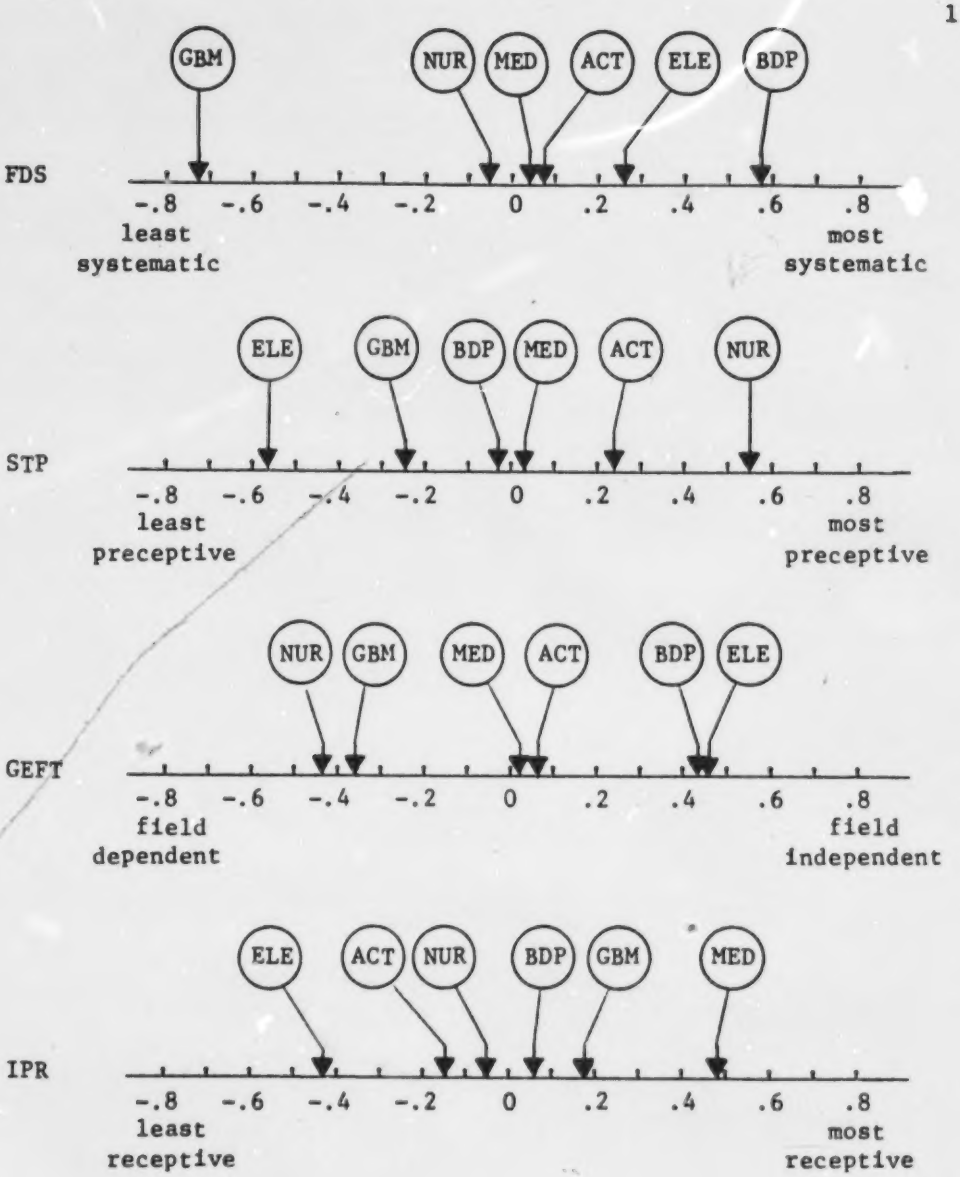
The group means (converted to Z-scores) are plotted in relation to the grand mean (zero) for each of the above cognitive style dimensions in Figure 36.

A brief cognitive style description of each subgroup is presented in Table 33. Group means beyond $\pm$ .25 deviations were regarded as extreme groups on each cognitive style continuum.

Table 33

Cognitive Style Descriptions of the Six Subgroups

Sequence of Study	Cognitive Style Dimension			
	FDS	STP	GEFT	IPR
ACT		preceptive		
BDP	systematic		field independent	
ELE	systematic	least preceptive	field independent	least receptive
GBM	least systematic	least preceptive	field dependent	receptive
MED				receptive
NUR		preceptive	field dependent	



acronyms:		
	ACT = accounting	GBM = general business management
	BDP = business data processing	MED = medical laboratory
	ELE = electronic engineering	NUR = nursing

Figure 36. Deviation of group means compared on the dimensions: systematic, preceptive, field articulation, receptive

The electronics engineering group (ELE) and the general business management (GBM) groups are described by all four cognitive style dimensions. ELE tend to be systematic, not preceptive, field independent, and not very receptive (methodical planners, step-by-step approach, analytical differential approach). GBM tend to be systematic, not very preceptive, field dependent, and receptive (methodical planners, step-by-step approach, global undifferentiated approach, focus on detail rather than relationships, sensitive to stimulus).

The business data processing group (BDP) is characterized by the two dimensions: systematic and field independent (methodical planners, step-by-step approach, analytical differentiated approach).

The nursing group (NUR) tend to be preceptive and field dependent (look for relationships between stimuli, global undifferentiated approach).

The accounting group tends to be preceptive (use of concepts and categories to code data, look for relationships between stimuli), while the medical laboratory group are characterized as receptive (sensitive to stimulus itself, focus on detail rather than relationships).

For the most part, the dimensions seem to be quite descriptive of the type of technological demands for each of the groups. The only difficulty in interpretation might be for the electronic engineering group who tend to be neither preceptive nor receptive (opposing extremes of McKenney's information gathering dimension).

From two discriminant functions, the dimensions that provide the most group separation are the two "orthogonal" sets: (1) field articulation and preceptive, and (2) preceptive, systematic, and

receptive. The first function discriminates with emphasis on preceptive and field dependence (use of categories and concepts to code data, looking for relationships between stimuli, global undifferentiated approach). The second function emphasizes three dimensions from McKenney's model: preceptive, systematic, and receptive (sensitive to stimuli, looking for relationships between stimuli, methodical, step-by-step approach).

Statistical Power:

In the investigation of question three pertaining to group differences for the cognitive style dimensions, Hypotheses 5 through 7 were posed. Decisions with respect to rejection or non-rejection of each null hypothesis were based on an alpha (Type I) error rate of .05. Although each overall null was rejected, only four of the eight cognitive style dimensions (systematic, preceptive, field articulation, and receptive) yielded significant univariate F-ratios in the analysis of variance.

The possibility of Type II (β) errors was investigated. To appraise the power ($1 - \beta$) of the F tests, estimates of power were calculated using techniques suggested by Winer (1971) and Cohen (1969). For each cognitive style measure, the alternative hypothesis was that a subgroup mean would differ from the grand mean by one fourth of the within population standard deviation.

The respective powers of the univariate ANOVA's for each of the cognitive style measures were approximately: ANSIE, .35; FDS, .98; GEFT, .96; IPR, .81; MFFT1, .45; MFFT2, .45; SWI, .45; and STP, .98.

Experimental design provided adequate power to test the alternative hypothesis concerning group differences on the systematic measure (FDS), the field articulation measure (GEFT), the receptive measure (IPR), and the preceptive measure (STP). The probability of committing a Type II error for these dimensions was slight.

However, on the dimensions of locus of control, latency--conceptual tempo, error scores--conceptual tempo, and intuitive, the low power estimates ($\leq .45$) suggest the possibility of Type II error existing. Altering the levels of significance from $\alpha = .05$ to $\alpha = .10$ increases the power from .45 to .56. The sensitivity of the statistical tests to determine differences must be questioned.

Because power varies inversely with variability, the standard deviations and ranges were examined for locus of control, conceptual tempo, and the intuitive measure (see the histograms and descriptive statistics in Appendix C). For each of these dimensions, ANSIE, MFFT1, MFFT2, and SWI, the large variability mitigates against large power values. Suggestions for future research would include further work on--and refinement of-- the cognitive style constructs and their respective measures.

Discussion and Recommendations

Six of the eight cognitive style dimensions appear to be related to learning of mathematics or to the sequences of study at the two-year college level. Three of the cognitive style measures were related to mathematics achievement and/or an aptitude for mathematics. The following recommendations are made for future research on cognitive

style in relation to mathematics education.

Because a large portion of this exploratory study was correlational in nature, a replication of the study, or cross-validation of segments of the study would be informative. In such a replication attention should be paid to the heterogeneity-homogeneity of the population (sample), especially in predictive studies or studies using regression analysis. Subjects should be chosen who are firmly established in their sequences of study. If cognitive style is related to the different sequences, "established" students successful in the sequence--or program of study--are more likely to exhibit, or be characterized by, the cognitive style dimensions. Sampling was to represent the campus first year to second year student ratio (3:1). The greater percentage of first year students may have modified or concealed possible "program of study" related cognitive style. With only 1/3 of the first year students returning, the possibility exists that the style demands of their chosen program of study may not be compatible with their cognitive style. Stringent control should be exercised over each facet of the data collection. Three tests were given to the subjects to complete outside of the testing sessions, and this may have adversely affected research outcomes.

For further investigation of the global construct of achievement in mathematics, a standardized validated instrument should be used, with possible subtests reflecting specific components of achievement. For further research involving aptitude, both verbal and non-verbal components should be included on the aptitude test.

Of greater importance would be the investigation of cognitive style dimensions as they relate to more specific behaviors, traits, components, skills, areas, etc. involved in the learning of mathematics (e.g. aspects of the problem solving process, concept attainment strategies, Piagetian conservation tasks, trait-treatment interactions, etc.). The mathematics constructs used in this study may have been too global to permit specific surfacing and intervention of the cognitive style dimensions.

With the relation of intelligence to several of the cognitive style dimensions--and to aptitude and achievement--incorporation of intelligence measures is suggested when working on cognitive-style research. By including both verbal and non-verbal (figural) means of assessment, more insight could be gained concerning the confounding effect intelligence seems to have upon cognitive style. Until substantiated by research indicating otherwise, cognitive style should continue to be researched--even if a possible overlap with intelligence exists. If the cognitive style dimensions were completely a factor of intelligence, the separate dimensions still provide information concerning the eclectic composite of intelligence. In some cases, the information gleaned from separate dimensions would be preferred over one single measure of intelligence.

With regard to the specific cognitive style dimensions, suggestions are made, first, for each dimension separately; then for the dimension in interaction with the rest of the cognitive style variables.

Locus of control (ANSIE)

Literature shows the relation of locus of control to age (Mink, 1976), academic achievement (Remainis, 1974), and ACT composite scores (Mink, 1976); Demahy (1974) reports learners are more efficient learners in the area of concept learning. Starr (1975) found locus of control to be correlated with mathematical ability in girls.

Herein, locus of control was not significantly correlated with any of the other variables--even the demographic variables. Reliabiltiy on the pilot study was .37, and was rather low in the major portion of the study (.64). Nowicki and Duke, instrumental in the construction of the scale, admit some items do not present consistently satisfactory psychometric characteristics. They recommend not omitting these items until further work is completed across a wider range of subjects. From the findings of this study, the scale could benefit from a thorough psychometric analysis with special attention on item analyses and internal consistency.

Viewed as a construct, locus of control may affect perceptual organization and conceptual categorization but does not seem to "fit" with cognitive style dimensions. The construct's past performance, in the area of achievement with other cognitive style dimensions seems to be restricted to the area of psychology and sociology (Lewis & Feldhusen, 1977; and Pappas & Nowicki, 1972). No relation existed, in this study, between locus of control and achievement in mathematics, nor aptitude, nor attitudes.

Conceptual tempo (MFFT1, MFFT2)

Fennema & Behr (1979), Shantz & Sigel (1967), Fein (1970), and Kagan et al. (1966) are several who advocate the study of conceptual tempo in the context of mathematical learning.

As investigated herein, neither measure of conceptual tempo (MFFT1 = average latency to first response; MFFT2 = number of total errors / test) was significantly related to achievement, aptitude or attitude. The only phase of the study in which conceptual tempo occurred was during investigation of the differential nature of cognitive style. MFFT1 was the fourth, and last, significant dimension to discriminate between groups--this was after intelligence was partialled. MFFT1 seemed to be independent of the intelligence measure, MFFT2 and intelligence were moderately related.

A decrease in the correlation coefficient between conceptual tempo and other variables could have been caused by low reliability, which increases error of measurement variation, resulting in general loss of power. The reliability coefficient for the error scores was .62. Low reliability of error scores and a moderate negative correlation between latency and errors, according to Ault, Mitchell, & Hartmann (1976), are some of the troublesome characteristics of this measure. A significant negative correlation (-.521) existed between MFFT1 and MFFT2.

One recommendation is an indepth study of this construct and the Matching Familiar Figures test. Is the low reliability due to lack of stability in the trait of conceptual tempo? In addition to investigating the trait, internal consistency reliability coefficients are needed to examine the instrument.

In relation to the other cognitive style dimensions, latency (MFFT1) is negatively related to both the receptive (IPR) and intuitive (SWI) measures. Total number of errors (MFFT2) is negatively related--with marginal significance--to the systematic measure (FDS); also to intelligence (APM) and aptitude (APT).

Field articulation (GEFT)

Field dependence-independence was significantly related to an aptitude for mathematics. When partialled of intelligence, GEFT no longer contributed to the multiple correlation, however. GEFT was a dimension on which the groups differed and was the most important discriminating variable in the first discriminant function. This finding seems to confirm an earlier finding (i.e. the longitudinal study of field dependence-field independence in academic development by Witkin et al., 1977). Future use of field articulation should be cognizant of the differential nature of this cognitive style dimension--especially in a predictive framework or correlational studies. In a regressional setting, separate and possibly different regression lines for each subgroup investigated might be more advantageous and valid; this suggestion was also made earlier by Crisco (1976).

Further research should be conducted on the relationship of GEFT to intelligence. These two were significantly related. Both assessment instruments utilize geometric non-verbal figures for measurement of the construct; both might have a common underlying factor of non-verbal intelligence. Of interest for investigation would be the relationship of field articulation to a highly reliable and valid measure of verbal intelligence.

McKenney information processing model (FDS,SWI,IPR,STP)

Because the McKenney model has virtually no research base, the recommendation is that this model should be more thoroughly investigated --especially in light of the contributions of the dimensions to almost all phases of this study.

Viewed as a two dimensional model, the two dimensions deal with information evaluation (systematic or intuitive) and information gathering (preceptive or receptive). The model was analyzed as four separate dimensions in this study. Findings indicate that the ends of each continuum are not necessarily bipolar. FDS and SWI significantly correlated (.352) as did STP and IPR (.364). However, the information gathering set does not significantly correlate with the information evaluation set. The idea of a two dimensional model was substantiated, not the bipolarity of each set.

Information evaluation. FDS and SWI were each related to achievement and aptitude. Partialled of intelligence, only SWI correlated with achievement, while both FDS and SWI remained significant correlates of aptitude. A noteworthy investigation would be an attempt to explain the relationship of both the systematic and intuitive measure to aptitude, and their overlap. Might some subjects "switch" from one style to another style within a task? This suggestion seems plausible for research, both on the global measure such as aptitude, as well as on more specific problem solving tasks.

Further research on each of the dimensions is encouraged. The interrelationship of the systematic measure (FDS), aptitude (APT), and intelligence is rather complex. Zero-order correlations are all

significant ($p < .001$) and are depicted in Figure 37.

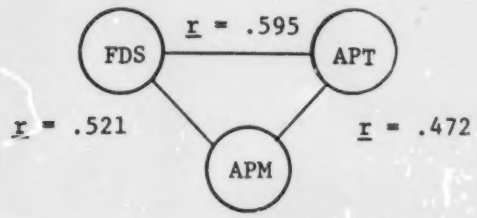


Figure 37. Zero-order correlations among the systematic (FDS), aptitude (APT), and intelligence (APM) measures

The possibility should be investigated that FDS may be a verbal related measure of intelligence, hence its correlation with the verbal measure of aptitude--even when partialled of intelligence (APM, non-verbal). If not a construct of intelligence, investigation of the systematic dimension as a cognitive style variable might have individual merit.

FDS was also a significant discriminator variable between groups. However, this occurred only when intelligence was not partialled. Figure 38 shows the group means (Z-scores) for the systematic measure (FDS), aptitude (APT) and intelligence (APM); the rank order of the six groups is virtually unchanged.

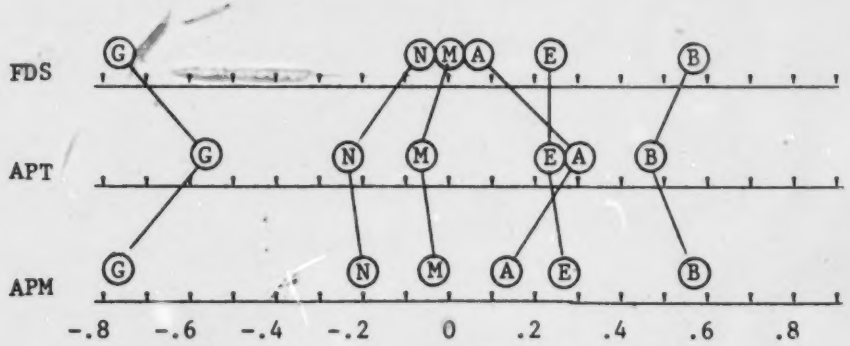


Figure 38. Deviation of group means compared on the measures: systematic (FDS), aptitude (APT), and intelligence (APM)

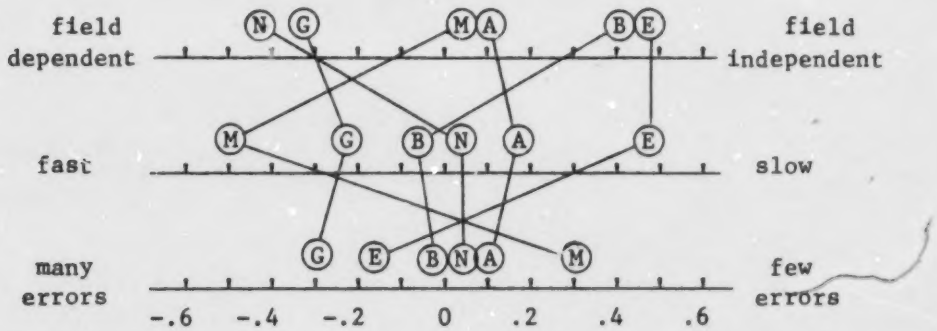
SWI, also related to both achievement and aptitude, does not seem to be related to an intelligence factor. Also of interest is the fact the groups do not differ significantly on this cognitive style dimension. Additional research is recommended on the validation of the intuitive construct.

Information gathering. The information gathering dimension, in the experimenter's opinion, requires intensive study. While not related to any of the mathematics criterion variables, nor to intelligence, both the preceptive (STP) and the receptive (IPR) measures are instrumental in group differentiation. From the findings, a recommendation is to focus investigative efforts on the construct as purported to be measured by the Kit of Factor-Referenced Cognitive Tests (Ekstrom et al., 1976) rather than as purported by McKenney. As used by McKenney, the constructs are similar to those measured by the field articulation measures. However, no significant correlations existed between GEFT and STP or IPR.

Both the construct preceptive and its measurement requires investigation and clarification. The role of STP is nebulous at best. Perhaps a starting point for the preceptive dimension is to attempt to relate it to divergent production, or ideational fluency.

The receptive measure (IPR) seems to assess perceptual speed--as suggested by the Kit of Factor-Referenced Cognitive Tests. (Ekstrom et al., 1976). Related to this might be decision speed, or even immediate perceptual memory. Recommendations for study relating IPR to these constructs seems highly desirable; IPR, viewed as perceptual speed, was negatively correlated with MFFT1 (latency for decision making using familiar figures).

Possible Interaction. Also of interest, and seemingly very worthy for investigation, is the apparent disordinal interaction between the field articulation measure (GEFT), the receptive measure (IPR) and number of errors (MFFT2). Figure 39 illustrates the group means on these three measures.



note: the scale for the receptive measure is reversed

Figure 39. Disordinal interaction between field articulation (GEFT), receptivity (IPR), and conceptual tempo errors (MFFT2)

As an example, the ELE group appears to be field independent (analytical), to have slower perceptual speed, and to make an average amount of errors. GBM tend to be field dependent (global), have quick perceptual speed, and make many errors. MED tend to be slightly field dependent with quick perceptual speed with relatively few errors. ELE (engineering) have an above average aptitude for mathematics; GBM (business management) have a below average aptitude; and MED (medical laboratory) have an average aptitude.

These illustrations are provided to draw attention to, and gain support for, the final recommendation of a more thorough statistical analysis of the complex interactive arrangements among cognitive style

dimensions in future research. The interactions among the cognitive style dimensions are further complicated by the fact the dimensions may be differentially exhibited in different subgroups under investigation.

The previous illustration--as was the intent of this research--was to draw attention to an apparent need for a closer more thorough analysis (in a multivariate sense) of the individual difference variables that may influence and further our understanding of the learning process. It is the belief of this researcher that such an approach must be taken to help understand the multifaceted nature of learning . . . then use this knowledge to increase people's learning potential. Unfortunately, as was quoted from Cronbach in Chapter I, " . . . to do this is no mean aspiration."

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APPENDIX A

STATISTICAL SUMMARY OF PILOT STUDY FINDINGS

Table 34

Means and Standard Deviations of Pilot Study Variables

Variable	Group GBM	ELE	MED	Total
AGE	29.56 (9.40)	24.78 (5.11)	22.56 (4.79)	25.63 (7.16)
SEX	0.56 (0.53)	0.89 (0.33)	0.33 (0.50)	0.59 (0.50)
CTIGPA	2.66 (0.77)	3.18 (0.61)	3.18 (0.43)	3.00 (0.64)
CTIMGP	3.22 (0.67)	3.33 (0.83)	3.50 (0.50)	3.35 (0.66)
ANSIE	9.78 (4.12)	6.44 (1.59)	8.22 (2.86)	8.15 (3.23)
FDS	9.92 (6.50)	12.08 (3.17)	13.02 (2.01)	11.67 (4.37)
GEFT	8.22 (6.16)	12.44 (4.53)	12.22 (4.68)	10.96 (5.35)
IPR	59.00 (9.87)	72.22 (11.38)	70.14 (14.32)	67.12 (12.96)
MFFT1	40.92 (19.80)	66.95 (46.19)	45.07 (17.01)	50.98 (31.65)
MFFT2	0.91 (0.57)	0.58 (0.35)	0.68 (0.32)	0.72 (0.43)
MFFT3	60.21 (21.60)	78.15 (42.27)	58.45 (15.75)	65.60 (29.19)
SWI	38.33 (11.26)	40.22 (9.09)	41.44 (4.28)	40.00 (8.47)
STP	23.56 (6.19)	22.11 (5.67)	24.89 (7.32)	23.52 (6.28)
APM1	7.67 (2.00)	8.89 (1.45)	8.11 (1.36)	8.22 (1.65)
MAT1	8.53 (6.00)	11.92 (3.99)	10.64 (4.28)	10.36 (4.86)
MAT2	15.03 (6.55)	18.48 (3.76)	16.78 (5.36)	16.77 (5.33)
RMAS	42.11 (28.29)	55.11 (9.88)	42.22 (19.52)	46.48 (20.79)

(Numbers in parentheses are the standard deviations)

Table 35

Pearson product moment pairwise correlations (n = 27)

Math Variable	Research Variables																
	AGE	SEX	CTI GPA	CTI MGP	ANSIE	APM1	FDS	GEFT	IPR	MFFT1	MFFT2	MFFT3	MAT1	MAT2	RMAS	SWI	STP
CTIMGP	-0.02	0.16	0.59 *	1.00	-0.13	0.52 *	0.40 *	0.35 *	0.02	0.19	-0.46 *	0.06	0.53 *	0.28	0.42 *	0.13	-0.06
MAT1	0.09	0.20	0.67 *	0.53 *	-0.45 *	0.66 *	0.65 *	0.47 *	0.02	0.30	-0.43 *	0.18	1.00	0.67 *	0.48 *	0.40 *	0.03
RMAS	-0.12	0.25	0.40 *	0.42 *	-0.24	0.40 *	0.39 *	0.42 *	0.42 *	0.22	-0.26	0.17	0.48 *	0.49 *	1.00	0.23	0.34 *

* significant correlations ($p < .05$) when considered pairwise

Table 36

Pilot--Standardized Regression Equations: Mathematics Achievement, Aptitude, and Attitudes

Criterion	Standardized Regression Equation	Coefficient of Determination	Significance of Regression
CTIMGP	$\hat{Y}$ = (.38)MAT1 + (-.34)MFFT2 + (.35)APM1 + (.20)ANSIE + (-.28 MAT2 + (.20)RMAS + (-.14)GEFT	R^2= 0.50	$_{.95}F_{7,19} < 2.70$
MAT1	$\hat{Y}$ = (.57)MAT2 + (.40)FDS + (.06)APM1 + (.84)MFFT1 + (.10)SWI + (-.20)STP + (.41)GEFT + (.51)MFFT2 + (.15)IPR + (-.56)MFFT3 + (.05)ANSIE + (.03)RMAS	R^2= 0.83	$_{.99}F_{12,14} < 5.65$
RMAS	$\hat{Y}$ = (.28)MAT2 + (.35)IPR + (.24)MFFT1 + (.32)APM1 + (.23)STP + (.12)ANSIE + (.12)FDS + (.07)GEFT	R^2= 0.53	$_{.95}F_{8,18} < 2.53$

APPENDIX B

MEANS AND STANDARD DEVIATIONS FOR ALL RESEARCH VARIABLES--MAJOR STUDY

Table 37

Means and Standard Deviations of All Variables, for each Subgroup and Total

	Technological Sequence													
	ACT (n=30)		BDP (n=30)		ELE (n=30)		GBM (n=30)		MSD (n=30)		NUR (n=30)		TOTAL (n=180)	
Variable	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
AGE	25.07	9.42	25.83	8.51	22.63	5.57	23.03	5.97	22.07	3.74	26.60	6.90	24.20	7.06
SEX	0.23	0.43	0.50	0.51	0.93	0.25	0.53	0.51	0.17	0.38	0.07	0.25	0.41	0.49
HSMPI	7.37	3.76	10.30	5.75	8.37	3.87	6.87	3.60	7.17	2.98	6.53	3.75	7.77	4.18
CTIGPA	2.85	0.64	3.32	0.57	2.93	0.71	2.59	0.60	2.91	0.61	3.09	0.50	2.95	0.64
CTIMGP	3.35	0.72	3.35	0.66	3.08	0.79	2.89	0.93	3.52	0.47	1.37	1.77	2.93	1.21
ANSIE	9.00	4.41	8.97	4.24	8.37	4.63	9.20	4.39	9.60	4.96	8.17	3.84	8.88	4.39
FDS	12.73	4.72	14.71	3.16	13.41	4.05	9.41	2.75	12.52	4.40	12.25	4.07	12.50	4.18
GEFT	11.10	5.04	13.33	4.12	13.37	4.03	9.40	5.07	11.03	4.77	8.60	5.10	11.14	4.98
IPR	64.63	12.32	67.97	14.40	59.73	14.13	69.33	16.38	73.57	15.93	66.57	15.09	66.97	15.17
MFFT1	42.88	22.61	48.38	21.88	35.57	16.73	45.01	32.20	49.65	26.36	48.92	29.46	45.07	25.50
MFFT2	9.50	6.33	10.13	6.80	10.77	7.29	12.07	5.07	8.13	5.02	9.63	7.19	10.04	6.38
SWI	45.17	5.80	44.37	6.58	43.10	6.74	40.77	9.86	44.63	5.65	42.73	9.50	43.46	7.59
STP	24.97	6.13	22.77	6.91	19.03	5.66	21.50	7.52	23.00	7.23	27.70	8.02	22.99	7.28
APM1	20.07	4.63	21.93	3.24	20.70	5.40	15.20	6.07	19.33	4.42	17.97	4.14	19.20	5.15
ACHRAW	49.93	18.90	65.33	21.28	64.57	16.95	64.90	14.07	54.53	15.92	76.53	12.89	62.63	18.73
MAT	12.15	3.84	12.70	4.65	12.12	5.13	8.21	3.37	10.35	3.67	9.34	4.87	10.81	4.55
RMAS	56.47	17.62	58.83	15.31	59.07	12.44	47.37	19.98	48.23	17.98	38.87	17.38	51.47	18.26
ACHSSC	50.00	10.00	49.64	10.21	50.30	10.03	50.00	10.00	50.01	10.17	50.63	9.52	50.09	9.86

APPENDIX C

HISTOGRAMS FOR THE SUBGROUPS FOR EACH OF THE VARIABLES INVESTIGATED

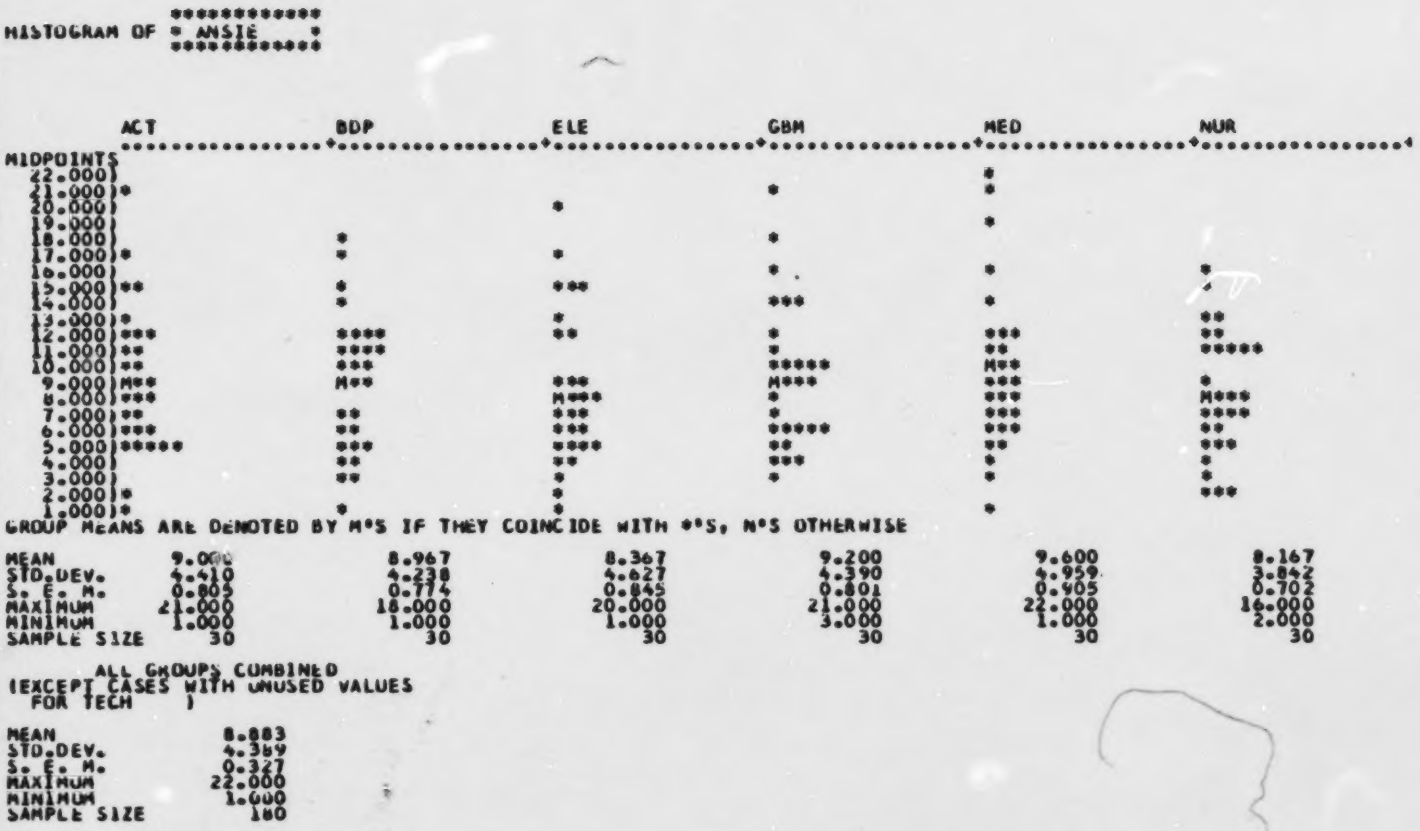


Figure 40. Histogram and descriptive statistics, by subgroup, for the locus of control measure.

```
HISTOGRAM OF  **********
              * FDS    *
              **********

          ACT             BDP             ELE             GBM             MED             NUR
MIDPOINTS
  21.000)
  20.000)***              *               **                                              *
  19.000)                 **              *                               *
  18.000)*                ***
  17.000)****             ***             ****                            ***             **
  16.000)**               ***             *                               *               **
  15.000)**               M****           *****           *               ******          ***
  14.000)*                ***             ****            *               **              **
  13.000)M*               ****            M***            *               M****           *****
  12.000)***              *               *               ***             ****            M*****
  11.000)**               *                               ***             **              ****
  10.000)**               ***             *               ******          *
   9.000)***                                               M***            *
   8.000)                                  *****           ***
   7.000)*                                                 ***                             **
   6.000)*                 *               *               **              *
   5.000)*                                                 *                               **
   4.000)**                                *               **
   3.000)                                                                  *
   2.000)                                                                  **
   1.000)                                                                                  *
   0.0  )
GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE

MEAN          12.733          14.708          13.408          9.408           12.517          12.250
STD.DEV.       4.722           3.162           4.053          2.747            4.399           4.068
S. E. M.       0.862           0.577           0.740          0.502            0.803           0.743
MAXIMUM       20.000          20.000          20.000         15.250           18.750          20.000
MINIMUM        4.000           6.000           4.250          4.000            1.750           0.750
SAMPLE SIZE       30              30              30             30               30              30

        ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
  FOR TECH    )

MEAN          12.504
STD.DEV.       4.184
S. E. M.       0.312
MAXIMUM       20.000
MINIMUM        0.750
SAMPLE SIZE      180
```

Figure 41. Histogram and descriptive statistics, by subgroup, for the systematic measure.

```
                ************
HISTOGRAM OF    * GEFT     *
                ************
```

```
          ACT                 BDP                 ELE                 GBM                 MED                 NUR
+---------+---------+---------+---------+---------+---------+---------+---------+---------+---------+---------+---------+
MIDPOINTS
  20.000)
  19.000)
  18.000)*                    **                  ***
  17.000)                     *******             ****                ***                 **                  *
  16.000)***                  ***                 *****               *                   **                  **
  15.000)*****                ****                ****                **                  *****               *
  14.000)*****                ***                 *                   **                  ****                ****
  13.000)***                  N                   M*                  **                  ***                 **
  12.000)**                   **                  ****                **                  *                   *
  11.000)M*                   **                                      **                  M                   *
  10.000)                     *                   **                  **                  **                  **
   9.000)                     *                   *                   N                   *                   M*
   8.000)*                    *                                       **                  *                   **
   7.000)                     *                   **                  *                   **                  **
   6.000)**                                                           **                  *                   *
   5.000)**                   ***                 *                   **                  *
   4.000)                                                             **                  **                  **
   3.000)                                         *                   ***                 *                   ****
   2.000)***                                                          *                   *                   ***
   1.000)*                                                            *                   *                   *
   0.0   )                                                                                *
  -1.000)
```

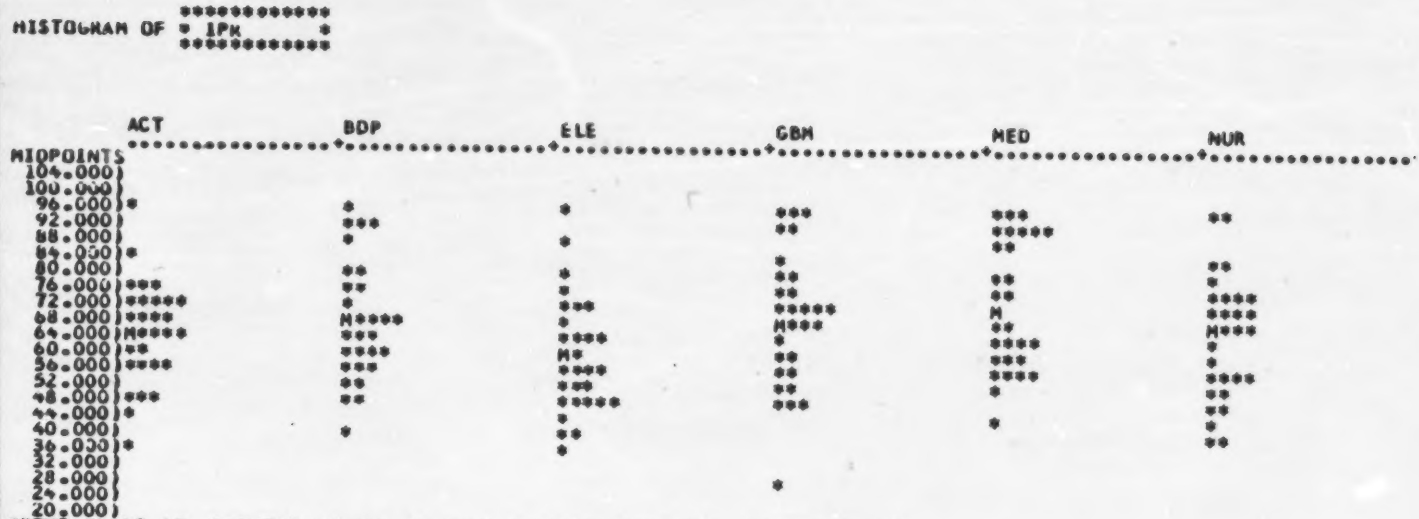
GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, N'S OTHERWISE

	ACT	BDP	ELE	GBM	MED	NUR
MEAN	11.100	13.333	13.367	9.400	11.033	8.600
STD.DEV.	5.040	4.124	4.030	5.069	4.767	5.103
S. E. M.	0.920	0.753	0.736	0.925	0.870	0.932
MAXIMUM	18.000	18.000	18.000	17.000	17.000	17.000
MINIMUM	1.000	5.000	3.000	1.000	0.0	1.000
SAMPLE SIZE	30	30	30	30	30	30

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR TECH)

MEAN	11.139
STD.DEV.	4.979
S. E. M.	0.371
MAXIMUM	18.000
MINIMUM	0.0
SAMPLE SIZE	180

Figure 42. Histogram and descriptive statistics, by subgroup, for the field articulation measure.



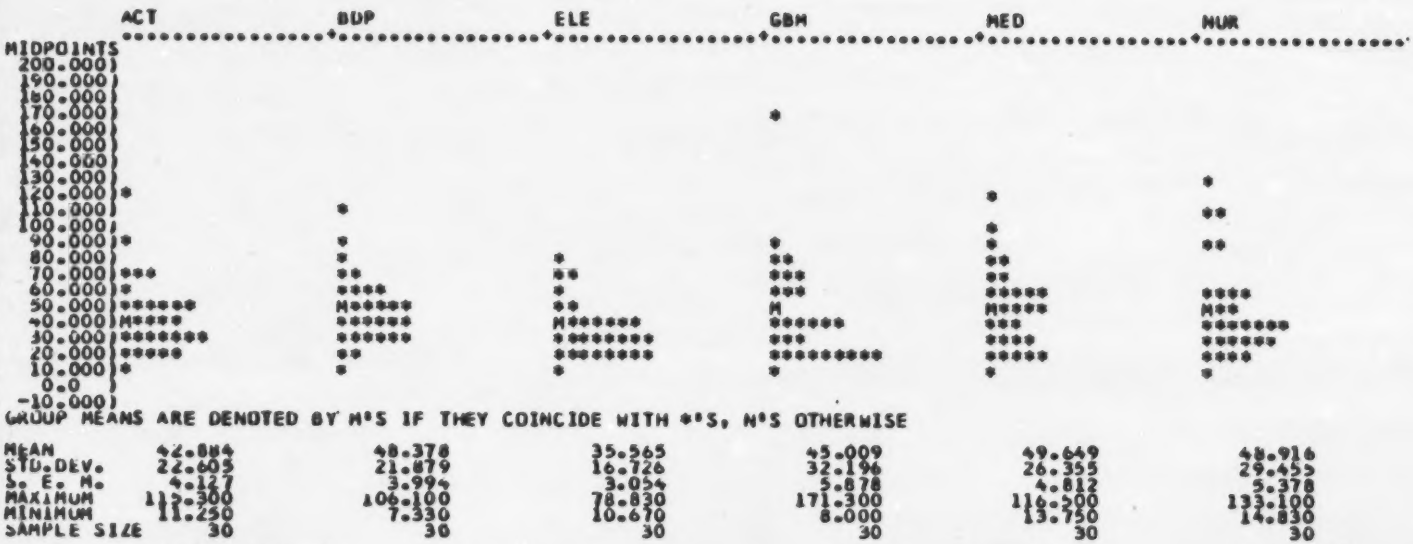
	ACT	BDP	ELE	GBM	MED	NUR
MEAN	64.633	67.967	59.733	69.333	73.567	66.567
STD.DEV.	12.322	14.399	14.130	16.384	15.930	15.090
S. E. M.	2.250	2.629	2.580	2.991	2.908	2.755
MAXIMUM	96.000	96.000	96.000	96.000	96.000	96.000
MINIMUM	35.000	40.000	38.000	28.000	44.000	39.000
SAMPLE SIZE	30	30	30	30	30	30

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR TECH)

MEAN	66.967
STD.DEV.	15.170
S. E. M.	1.131
MAXIMUM	96.000
MINIMUM	28.000
SAMPLE SIZE	180

Figure 43. Histogram and descriptive statistics, by subgroup, for the receptive measure.

HISTOGRAM OF * MFFTL *



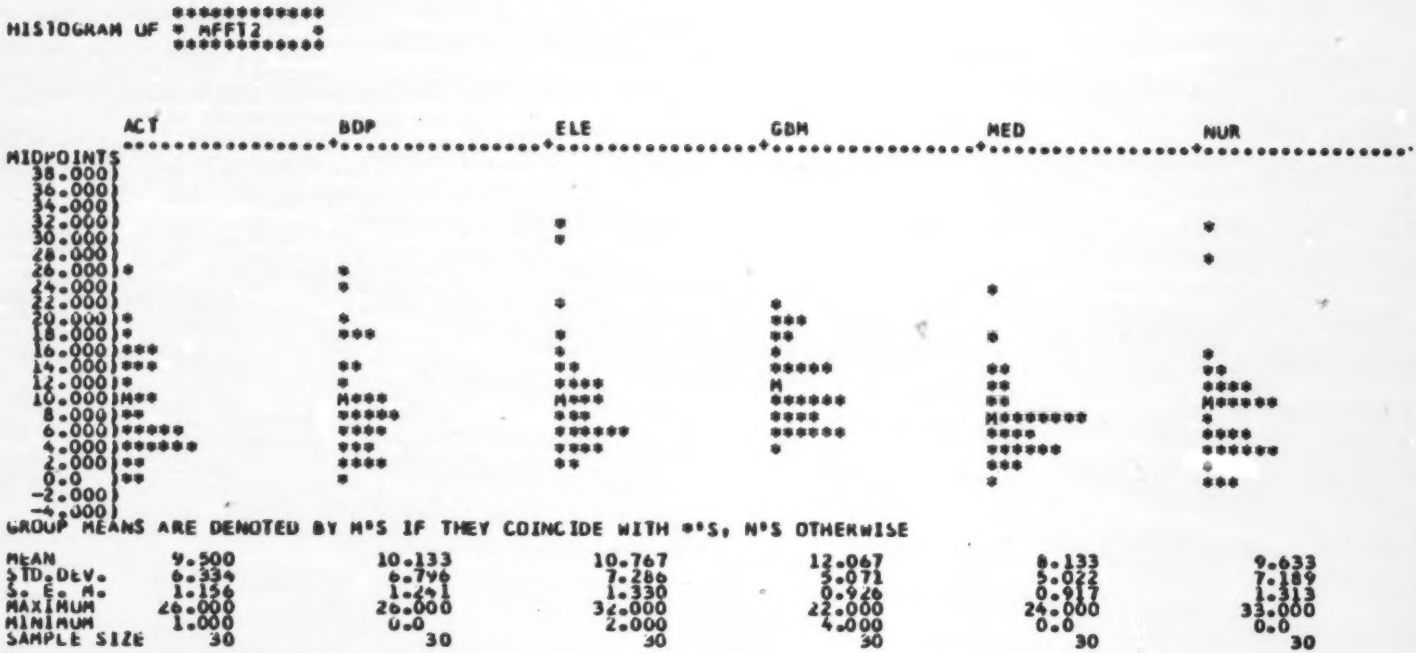
GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE

	ACT	BDP	ELE	GBM	MED	NUR
MEAN	42.884	48.378	35.565	45.009	49.649	48.916
STD.DEV.	22.605	21.879	16.726	32.196	26.355	29.455
S. E. M.	4.127	3.994	3.054	5.878	4.812	5.378
MAXIMUM	113.300	106.100	78.830	171.300	116.500	133.100
MINIMUM	11.250	7.330	10.670	8.000	13.750	14.830
SAMPLE SIZE	30	30	30	30	30	30

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR TECH)

MEAN	45.067
STD.DEV.	25.504
S. E. M.	1.401
MAXIMUM	171.300
MINIMUM	7.330
SAMPLE SIZE	180

Figure 44. Histogram and descriptive statistics, by subgroup, of latency scores for the conceptual tempo measure.



	ACT	BDP	ELE	GDM	MED	NUR
MEAN	9.500	10.133	10.767	12.067	8.133	9.633
STD.DEV.	6.334	6.796	7.286	5.071	5.022	7.189
S. E. M.	1.156	1.241	1.330	0.926	0.917	1.313
MAXIMUM	26.000	26.000	32.000	22.000	24.000	33.000
MINIMUM	1.000	0.0	2.000	4.000	0.0	0.0
SAMPLE SIZE	30	30	30	30	30	30

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR TECH)

MEAN	10.039
STD.DEV.	6.378
S. E. M.	0.475
MAXIMUM	33.000
MINIMUM	0.0
SAMPLE SIZE	180

Figure 45. Histogram and descriptive statistics, by subgroup, of error scores for the conceptual tempo measure.

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                ***********
HISTOGRAM OF    * VAR1    *
                ***********
```

MIDPOINTS	ACT	BDP	ELE	GBM	MED	NUR
54.000)						
52.000)						
50.000)	********	**********	******	**	*******	*******
48.000)	********	***	*****	*****	******	******
46.000)	M**	**	***	*******	***	******
44.000)	***	M*	M*	*	M**	*
42.000)	**	****	****	****	**	M
40.000)	**		**	M**	****	*
38.000)		***	**	*	**	*
36.000)	**		*		*	*
34.000)		***	*	**	*	**
32.000)		*	*			
30.000)	*		**			
28.000)	*		*	*		
26.000)		*			*	
24.000)				*		**
22.000)						*
20.000)						
18.000)				**		
16.000)				*		*
14.000)						
12.000)						

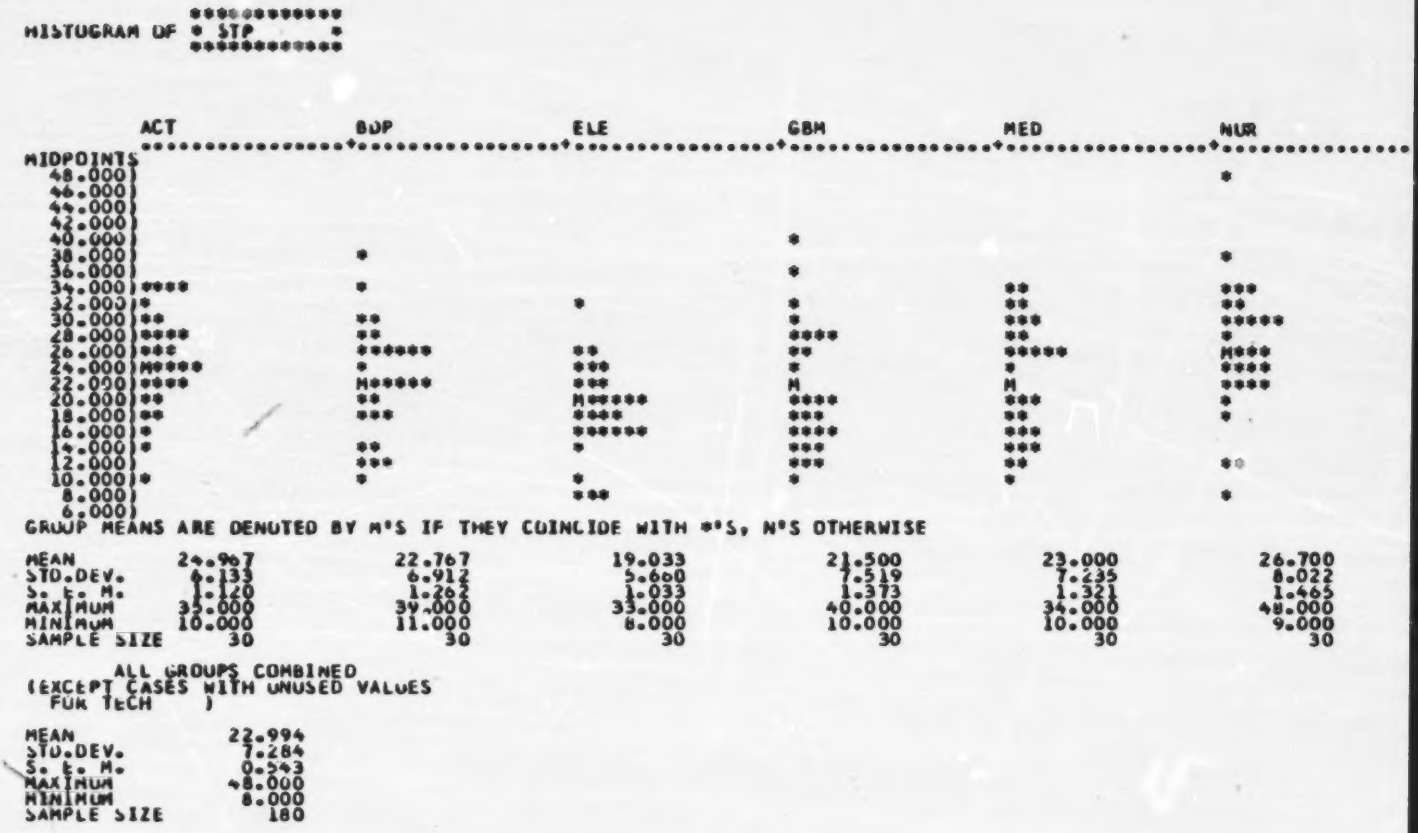
GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, M'S OTHERWISE

	ACT	BDP	ELE	GBM	MED	NUR
MEAN	45.167	44.367	43.100	40.767	44.633	42.733
STD.DEV.	5.796	6.578	6.738	9.863	5.654	9.501
S. E. M.	1.058	1.201	1.230	1.801	1.032	1.735
MAXIMUM	50.000	50.000	50.000	50.000	50.000	50.000
MINIMUM	29.000	26.000	28.000	17.000	27.000	17.000
SAMPLE SIZE	30	30	30	30	30	30

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
FOR TECH)

MEAN	43.461
STD.DEV.	7.587
S. E. M.	0.565
MAXIMUM	50.000
MINIMUM	17.000
SAMPLE SIZE	180

Figure 46. Histogram and descriptive statistics, by subgroup, for the intuitive measure.

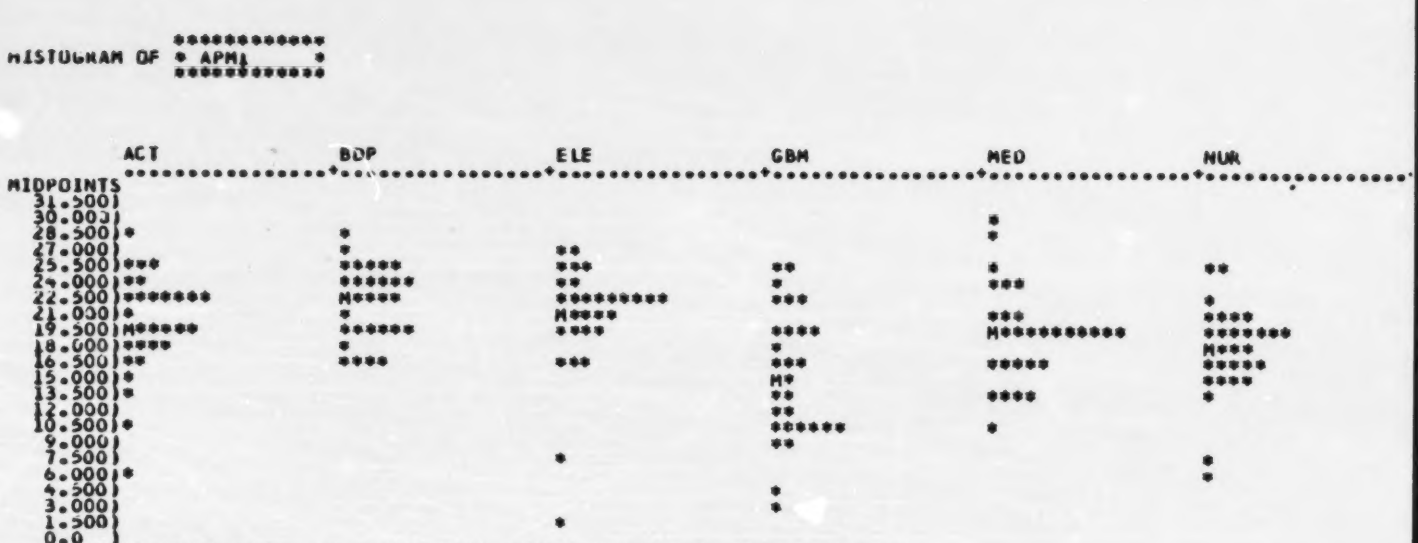


	ACT	BUP	ELE	GBM	MED	NUR
MEAN	24.967	22.767	19.033	21.500	23.000	26.700
STD.DEV.	6.133	6.912	5.660	7.519	7.235	8.022
S. E. M.	1.120	1.262	1.033	1.373	1.321	1.465
MAXIMUM	35.000	39.000	33.000	40.000	34.000	48.000
MINIMUM	10.000	11.000	8.000	10.000	10.000	9.000
SAMPLE SIZE	30	30	30	30	30	30

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
FOR TECH)

MEAN	22.994
STD.DEV.	7.284
S. E. M.	0.543
MAXIMUM	48.000
MINIMUM	8.000
SAMPLE SIZE	180

Figure 47. Histogram and descriptive statistics, by subgroup, for the preceptive measure.



	ACT	BDP	ELE	GBM	MED	NUR
MEAN	20.067	21.933	20.700	15.200	19.333	17.967
STD.DEV.	4.631	3.237	5.402	6.065	4.420	4.140
S. E. M.	0.845	0.591	0.986	1.107	0.807	0.756
MAXIMUM	28.000	28.000	27.000	26.000	30.000	25.000
MINIMUM	6.000	16.000	1.000	3.000	10.000	6.000
SAMPLE SIZE	30	30	30	30	30	30

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR TECH)

MEAN	19.200
STD.DEV.	5.147
S. E. M.	0.384
MAXIMUM	30.000
MINIMUM	1.000
SAMPLE SIZE	180

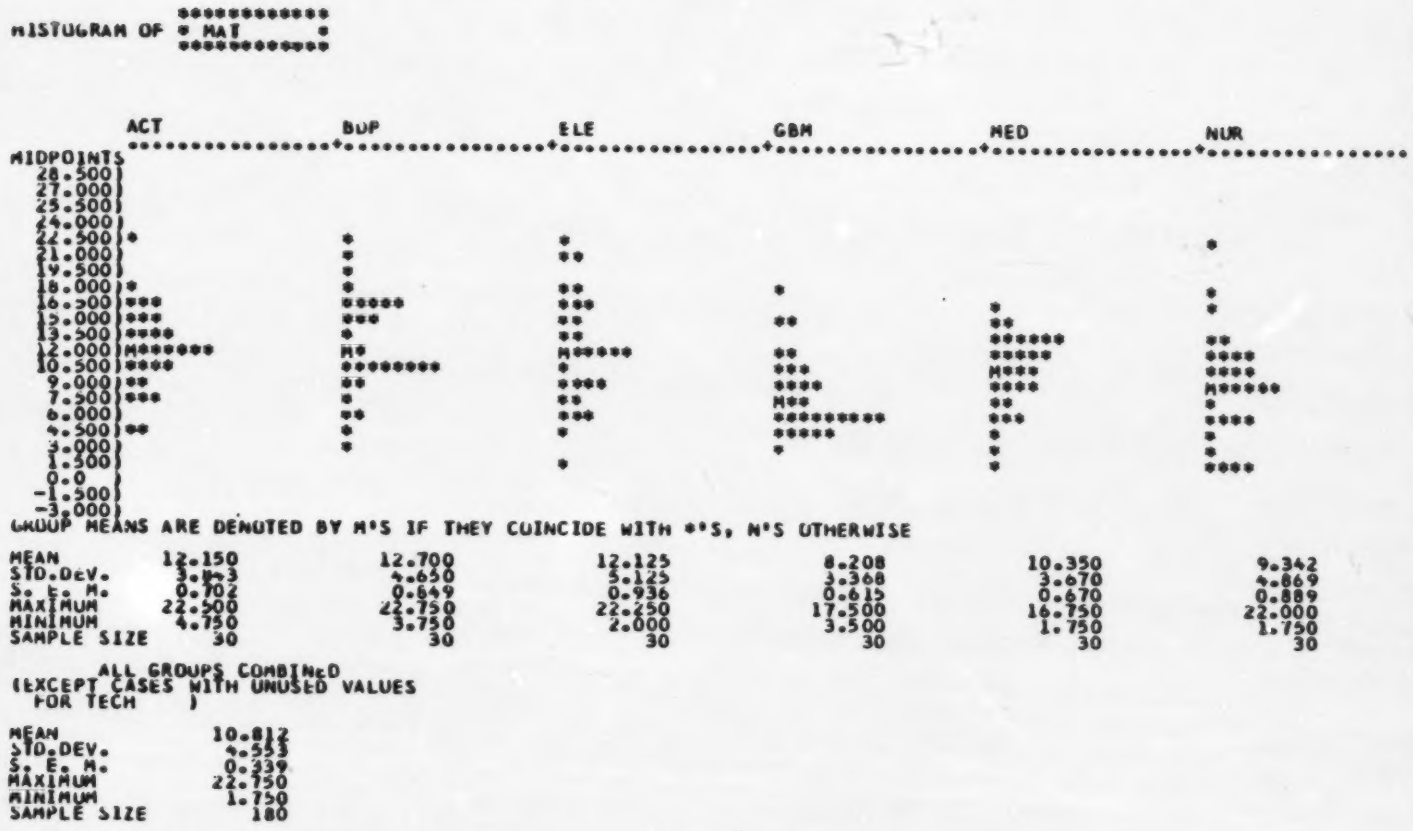
Figure 48. Histogram and descriptive statistics, by subgroup, for the intelligence measure.

	ACT	BDP	ELE	GBM	MED	NUR
MEAN	50.000	49.635	50.297	50.000	50.011	50.632
STD.DEV.	10.000	10.208	10.031	10.000	10.171	9.520
S. E. M.	1.826	1.864	1.831	1.826	1.857	1.738
MAXIMUM	69.617	65.309	62.983	62.862	71.398	65.014
MINIMUM	28.666	25.484	32.206	27.331	24.747	31.030
SAMPLE SIZE	30	30	30	30	30	30

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR TECH)

MEAN	50.096
STD.DEV.	9.655
S. E. M.	0.735
MAXIMUM	71.398
MINIMUM	24.747
SAMPLE SIZE	180

Figure 49. Histogram and descriptive statistics, by subgroup, for the standardized mathematics achievement scores.



	ACT	BUP	ELE	GBM	MED	NUR
MEAN	12.150	12.700	12.125	8.208	10.350	9.342
STD.DEV.	3.443	4.650	5.125	3.368	3.670	4.869
S. E. M.	0.702	0.649	0.936	0.615	0.670	0.889
MAXIMUM	22.500	22.750	22.250	17.500	16.750	22.000
MINIMUM	4.750	3.750	2.000	3.500	1.750	1.750
SAMPLE SIZE	30	30	30	30	30	30

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES FOR TECH)

MEAN	10.812
STD.DEV.	4.553
S. E. M.	0.339
MAXIMUM	22.750
MINIMUM	1.750
SAMPLE SIZE	180

Figure 50. Histogram and descriptive statistics, by subgroup, for the measure of aptitude for mathematics.

```
HISTOGRAM OF  ********** 
              * RMAS     *
              ********** 
```

MIDPOINTS	ACT	BUP	ELE	GBM	MED	NUR
84.000						
80.000	*	*	*	*	*	
76.000	**	***	***	**	*	**
72.000	*****	*****	**	*	*	
68.000	**	***	***	*		
64.000	***	*		*	****	
60.000	*	M**	M*******	*****	**	**
56.000	M**	****	*****	***	***	***
52.000	****	****	**	**	****	**
48.000	***		*	M	N	
44.000	***	*	***		****	**
40.000			**	**	****	M*
36.000		*		**	*	**
32.000		*		*	*	***
28.000		***	*	**		*****
24.000						**
20.000	**			****	*	**
16.000				**	*	*
12.000					*	*
8.000	*				*	*
4.000						
0.0						

GROUP MEANS ARE DENOTED BY M'S IF THEY COINCIDE WITH *'S, N'S OTHERWISE

	ACT	BUP	ELE	GBM	MED	NUR
MEAN	56.467	58.833	59.067	47.367	48.233	38.867
STD.DEV.	17.620	15.308	12.437	19.977	17.480	17.376
S. E. M.	3.217	2.795	2.271	3.647	3.283	3.172
MAXIMUM	79.000	79.000	80.000	79.000	80.000	77.000
MINIMUM	7.000	28.000	27.000	16.000	8.000	9.000
SAMPLE SIZE	30	30	30	30	30	30

ALL GROUPS COMBINED
(EXCEPT CASES WITH UNUSED VALUES
FOR TECH)

MEAN	51.472
STD.DEV.	18.260
S. E. M.	1.361
MAXIMUM	80.000
MINIMUM	7.000
SAMPLE SIZE	180

Figure 51. Histogram and descriptive statistics, by subgroup, for the measure of attitudes toward mathematics.

APPENDIX D

INTRODUCTORY MATERIALS FOR THE "LEARNING STYLE" PARTICIPANTS

Additional written introduction to the "learning style" project

Name or Number _____

Directions

* Place your name or number at the top of this page; use the same identification mark on all tests that you take.

* Read over this introductory page - if you have any questions, please ask .

THANK YOU, in advance, for participating in this research study that will be focussing on cognitive (learning) styles. By taking all eleven test instruments listed below, a profile of your learning style will be identified. We all learn in different ways. Some ways of learning are suited to your style of learning, some are not. Consequently, some tests will be easier for you than others; some tests may seem harder. The key is to take all of the instruments and do the best you can. Only this way will your personal cognitive style be accurately determined.

When the results of all these instruments are scored and interpreted, you will know more about your own individual style of learning. The results will be available to you in a few weeks or so, and will be kept strictly confidential. The results have no influence on your course work at Columbus Technical Institute.

Test Instruments

_____ Adult Nowicki-Strickland Internal-External Scale
_____ Following Directions
_____ Group Embedded Figures Test
_____ Identical Pictures
_____ Matching Familiar Figures Test
_____ Scrambled Words
_____ Symbols Test
_____ Advanced Progressive Matrices
_____ Standardized Achievement Test
_____ Mathematics Aptitude Test
_____ Revised Math Attitude Scale

* Wait for directions before beginning each individual test instrument. If directions are written, please read the directions very carefully.

Thank you.

Upon completion of all assessment instruments, each participant in the "learning style" project was presented an information packet which contained the following descriptive materials:

(a) an introduction to learning styles, and more specifically, cognitive style

(b) a listing of the goals of the study

(c) a brief glossary providing definitions of much of the cognitive style terminology

(d) a four page interpretative guide to assist each student in interpreting their "learning style" profile

(e) a profile sheet, showing--for each cognitive style dimension--the average score for all participants, the average scores for all first year students in the participant's technological sequence, and the average scores for all second year students in the participant's technological sequence.

Each participant--from a individual computer printout--plotted their scores on the profile sheet for comparison to the averages cited above.

(f) a summary table of the average scores (means) for each test for each of the separate technological sequences

(g) a list of references for further reading for those interested

Upon completion of the study, participants would be made available a complete report and compilation of all findings from the research study.

APPENDIX E

COMPLETE LISTING OF ALL RESEARCH VARIABLES AND ACRONYMS

Listing of Research Acronyms and Meanings

Demographic variables:

AGE = age

SEX = sex

HSMPI = high school mathematics product index (number of courses times grade point average)

CTIGPA = college cumulative grade point average (a 4.0 is equivalent to an A)

CTIMGP = college cumulative mathematics grade point average

CTIMPI = college mathematics product index

Cognitive style variables:

ANSIE = measure of locus of control; test used was the Adult Nowicki-Strickland Internal External Control Scale

FDS = measure of the systematic dimension; test used was the Following Directions test

GEFT = measure of field dependence-field independence; test used was the Group Embedded Figures Test

IPR = measure of the receptive dimension; test used was the Identical Pictures test

MFFT1, MFFT2, MFFT3 = measures of reflective-impulsive (conceptual tempo) test used was the Matching Familiar Figures Test
- average latency to first response
- number of total errors per test
- average total time per item

SWI = measure of intuitive dimension, test used was the Scrambled Words test

STP = measure of the preceptive dimension, test used was the Symbols test

Intelligence, of general reasoning variable:

APM1, APM2 = measures of intellectual efficiency test used was the Advanced Progressive Matrices Set II
- number correct
- number correct as percent of number attempted

APM = acronym used in major portion of research referring to the one measure (APM1) used in the analyses

Criterion variables (mathematics related variables):

ACHRAW = measure of mathematics achievment; measure is recorded as raw score percent; tests used were the Columbus Technical Institute's Mathematics Placement Tests

MAT1, MAT2 = measures of aptitude for mathematics tests used are to the right
- Mathematics Aptitude Test
- Necessary Arithmetic Operations Test

RMAS = measure of attitudes toward mathematics; the test used was the Revised Math Attitude Scale

ACHSSC = the corresponding achievement measures above, but converted to standard scores with a mean of 50 and a standard deviation of 10

ACH = used in most of the analyses to refer to ACHSSC

APT = used in most of the analyses to refer to the aptitude measure--MAT1 above; (MAT2 was used in the pilot study only)

ATT = used in most analyses to refer to the attitude measure--RMAS

Grouping variables (technological sequence):

Students representing the mathematics sequence of study for:

ACT = accounting technology

BDP = business data processing

ELE = electonics engineering

GBM = general business management

MED = medical laboratory technology

NUR = nursing

APPENDIX F

RAW DATA RECORDS FOR ALL PARTICIPANTS (n = 180)--BY SUBGROUP

To facilitate additional analyses, raw data records are provided for all participants in the major portion of the research study. The 180 participants are subdivided into the six sequences of mathematical study: (1) accounting, (2) business data processing, (3) electronic engineering, (4) general business management, (5) medical laboratory, and (6) nursing. In each group of 30--listed on separate pages--two lines of data are given for each participant.

For each subject, the following data is given:

line 1 : identification number; techn.logy code; age; sex; high school mathematics product i..dex; college cumulative grade point average; college cumulative mathematics grade point average; college mathematics product index; locus of control measure; systematic measure; field articulation measure; receptive measure

line 2: conceptual tempo-mean latency; conceptual tempo-number of errors per test; conceptual tempo-mean total time per item; intuitive measure; preceptive measure; intelligence measure-number correct; intelligence measure-number correct as percent of number attempted; achievement raw score; aptitude for mathematics measure; attitude toward mathematics measure; achievement score-standardized

Raw data records for technological sequence: accounting

139 1	18 0	6.0	2.88	2.0	2.0	6.0	8.75	15.0	74.0	
33.27	8.0	44.0	44.0	14.0	22.0	73.0	47.0	5.0	57.0	48.44759
096 1	18 0	5.0	1.5	2.0	2.0	15.0	17.5	14.0	50.0	
34.08	2.0	37.42	49.0	10.0	20.0	67.0	37.0	14.25	20.0	43.15520
141 1	18 0	5.0	2.04	2.5	5.0	5.0	10.0	5.0	76.0	
51.33	6.0	66.67	50.0	26.0	6.0	20.0	49.0	9.25	45.0	49.50609
011 1	20 0	8.0	3.27	4.0	4.0	6.0	16.25	14.0	57.0	
34.0	10.0	82.42	50.0	26.0	26.0	40.0	77.0	15.25	72.0	64.32458
120 1	20 0	7.0	2.01	3.33	9.99	10.0	6.0	16.0	68.0	
26.91	7.0	35.5	36.0	24.0	18.0	62.0	23.0	7.5	77.0	35.74600
058 1	23 0	13.0	3.26	4.0	8.0	5.0	4.0	13.0	69.0	
33.5	7.0	42.08	41.0	22.0	15.0	54.0	60.0	7.75	58.0	55.32759
060 1	19 1	3.0	3.63	4.0	4.0	9.0	17.5	18.0	96.0	
68.58	1.0	69.47	48.0	31.0	28.0	93.0	80.0	22.5	66.0	65.91229
152 1	21 0	5.0	2.43	3.0	6.0	5.0	12.5	14.0	68.0	
42.08	4.0	48.08	48.0	20.0	23.0	77.0	43.0	13.5	54.0	46.33069
001 1	30 0	4.0	4.0	4.0	8.0	1.0	17.75	5.0	63.0	
35.25	5.0	46.17	50.0	28.0	18.0	69.0	43.0	16.0	45.0	46.33069
088 1	35 0	4.0	4.0	4.0	4.0	2.0	12.75	13.0	71.0	
45.92	3.0	57.03	50.0	30.0	18.0	82.0	43.0	10.5	7.0	46.33069
157 1	38 0	15.0	3.81	4.0	12.0	6.0	20.0	15.0	56.0	
52.5	5.0	61.75	50.0	24.0	24.0	92.0	60.0	12.5	47.0	55.32759
024 1	31 1	6.0	3.31	4.0	4.0	8.0	5.5	14.0	61.0	
87.36	1.0	94.27	49.0	26.0	20.0	83.0	40.0	11.75	50.0	44.74300
122 1	25 0	5.0	2.71	3.5	7.0	15.0	9.25	11.0	69.0	
59.92	5.0	63.25	46.0	23.0	23.0	77.0	23.0	13.75	67.0	35.74600
070 1	18 0	11.0	3.18	4.0	4.0	11.0	12.0	15.0	68.0	
71.67	4.0	74.33	48.0	29.0	19.0	63.0	73.0	14.75	74.0	62.20769
008 1	20 1	8.0	2.42	4.0	4.0	7.0	20.0	13.0	75.0	
23.75	26.0	35.33	50.0	22.0	14.0	63.0	63.0	14.25	47.0	56.91530
171 1	27 1	3.0	2.65	3.0	6.0	5.0	13.75	16.0	48.0	
18.25	14.0	38.67	40.0	24.0	23.0	85.0	30.0	8.75	74.0	39.45059
106 1	18 1	5.0	3.08	4.0	4.0	14.0	10.75	8.0	35.0	
115.3	7.0	104.3	47.0	16.0	17.0	59.0	70.0	7.75	73.0	60.62000
004 1	22 1	11.25	1.76	3.0	3.0	12.0	17.5	2.0	55.0	
46.42	11.0	75.67	50.0	19.0	23.0	77.0	70.0	16.75	54.0	60.62000
031 1	26 0	5.0	2.43	2.0	2.0	4.0	20.0	16.0	66.0	
17.17	14.0	25.3	42.0	29.0	26.0	90.0	53.0	14.5	20.0	51.62249
034 1	20 0	15.0	2.48	2.0	2.0	9.0	12.25	6.0	71.0	
18.67	10.0	33.58	46.0	26.0	25.0	83.0	40.0	12.25	75.0	44.74300
030 1	17 0	6.0	2.53	3.0	3.0	10.0	9.0	14.0	50.0	
30.0	15.0	50.9	48.0	24.0	24.0	80.0	27.0	10.0	72.0	37.86290
182 1	28 0	7.0	2.82	3.5	7.0	5.0	9.75	11.0	63.0	
16.67	17.0	38.5	36.0	34.0	14.0	56.0	53.0	10.0	69.0	51.62249
138 1	21 0	10.0	3.09	4.0	4.0	17.0	11.5	2.0	73.0	
32.5	6.0	36.75	48.0	34.0	21.0	70.0	77.0	11.5	66.0	64.32458
146 1	20 0	10.0	2.45	3.5	7.0	12.0	13.0	15.0	63.0	
11.25	21.0	25.5	42.0	19.0	18.0	60.0	47.0	10.5	25.0	48.44759
115 1	41 1	14.0	2.84	3.75	15.0	11.0	4.5	2.0	78.0	
32.75	17.0	54.83	31.0	34.0	22.0	73.0	87.0	17.5	78.0	69.61690
078 1	35 0	6.0	3.83	4.0	8.0	8.0	12.0	6.0	56.0	
39.33	16.0	78.33	49.0	32.0	19.0	79.0	50.0	11.5	44.0	50.03529
182 1	20 0	5.0	2.43	2.5	5.0	7.0	7.0	1.0	61.0	
30.08	18.0	54.83	44.0	22.0	11.0	36.0	10.0	4.75	51.0	28.86591
099 1	23 0	0.0	2.88	3.0	3.0	8.0	15.0	12.0	73.0	
46.08	15.0	77.83	49.0	28.0	20.0	67.0	33.0	11.5	60.0	41.03830
065 1	19 0	8.0	3.02	4.0	4.0	15.0	17.5	15.0	84.0	
80.75	4.0	87.5	44.0	35.0	23.0	77.0	50.0	12.25	52.0	50.03529
181 1	61 0	11.0	2.44	3.0	6.0	21.0	15.75	12.0	46.0	
39.17	8.0	56.25	50.0	24.0	17.0	57.0	40.0	10.5	63.0	44.74300

Raw data records for technological sequence: business data processing

098 2	46 1	6.0	3.85	4.0	12.0	6.0	13.75	16.0	67.0	
34.0	10.0	73.0	39.0	22.0	21.0	84.0	48.0	17.0	53.0	41.31819
140 2	18 0	11.0	2.91	2.5	5.0	7.0	17.5	17.0	89.0	
32.83	9.0	47.58	50.0	46.0	24.0	80.0	55.0	11.0	53.0	44.67699
090 2	28 0	4.0	3.28	3.0	9.0	15.0	16.25	15.0	79.0	
22.16	18.0	37.0	50.0	27.0	19.0	64.0	43.0	5.25	38.0	38.91908
089 2	25 1	3.0	2.87	3.25	13.0	11.0	15.5	17.0	57.0	
35.92	4.0	43.5	45.0	23.0	22.0	92.0	38.0	11.5	44.0	36.51490
009 2	24 1	10.0	3.9	3.67	11.0	3.0	13.74	8.0	62.0	
33.25	11.0	54.92	53.0	22.0	24.0	83.0	88.0	13.75	61.0	60.51118
147 2	20 1	6.0	3.3	3.5	7.0	10.0	15.25	15.0	75.0	
73.25	6.0	80.91	35.0	18.0	24.0	80.0	73.0	12.5	69.0	53.31380
024 2	25 1	6.0	3.03	3.2	16.0	4.0	12.25	11.0	63.0	
31.67	19.0	58.67	35.0	26.0	20.0	71.0	35.0	10.5	34.0	35.08049
132 2	23 0	14.0	3.76	4.0	8.0	6.0	18.75	17.0	56.0	
61.75	5.0	66.17	50.0	31.0	24.0	89.0	85.0	17.25	74.0	58.11200
126 2	18 1	4.0	2.27	3.0	3.0	12.0	13.75	14.0	66.0	
21.17	14.0	34.17	50.0	15.0	25.0	83.0	75.0	9.75	55.0	54.27339
085 2	26 1	9.0	3.8	4.0	12.0	1.0	17.75	17.0	50.0	
100.1	3.0	110.2	39.0	22.0	25.0	96.0	98.0	16.25	89.0	65.30939
082 2	19 0	12.0	3.55	3.67	11.0	9.0	10.5	17.0	94.0	
44.44	8.0	53.33	49.0	23.0	24.0	89.0	75.0	16.75	78.0	54.27339
111 2	31 1	5.0	2.38	2.33	7.0	14.0	15.0	17.0	62.0	
39.58	4.0	43.33	50.0	22.0	22.0	73.0	65.0	22.75	30.0	49.47519
071 2	35 1	14.0	3.0	3.0	6.0	5.0	11.25	18.0	40.0	
64.83	2.0	67.17	49.0	12.0	23.0	92.0	68.0	15.25	77.0	50.91469
169 2	19 1	6.0	1.96	1.6	8.0	11.0	13.25	12.0	65.0	
32.25	11.0	80.0	26.0	14.0	17.0	61.0	15.0	6.25	28.0	25.48401
002 2	20 1	9.0	3.53	3.33	10.0	5.0	17.5	17.0	82.0	
40.4	14.0	53.75	50.0	29.0	27.0	90.0	95.0	16.0	68.0	63.86989
028 2	18 0	17.0	3.55	4.0	12.0	12.0	18.75	5.0	53.0	
26.75	7.0	39.5	45.0	26.0	18.0	64.0	83.0	11.0	62.0	58.11200
026 2	36 0	8.0	2.82	2.5	10.0	17.0	12.75	14.0	68.0	
81.75	10.0	91.9	50.0	20.0	16.0	53.0	53.0	18.0	63.0	43.71750
109 2	22 0	13.0	3.77	3.67	11.0	2.0	17.75	14.0	80.0	
38.33	9.0	83.33	50.0	20.0	28.0	93.0	70.0	9.0	59.0	51.87430
005 2	33 0	4.0	2.33	1.8	9.0	9.0	17.50	5.0	50.0	
47.67	9.0	62.67	50.0	12.0	20.0	67.0	65.0	15.75	52.0	49.47519
024 2	19 1	12.0	3.46	3.67	11.0	18.0	15.0	18.0	55.0	
57.67	21.0	89.5	47.0	35.0	22.0	73.0	75.0	10.0	75.0	54.27339
036 2	33 0	23.0	4.0	4.0	20.0	11.0	13.0	16.0	52.0	
73.3	0.0	73.3	42.0	13.0	25.0	93.0	93.0	10.75	74.0	62.91029
055 2	28 0	4.0	3.94	4.0	20.0	10.0	10.5	16.0	72.0	
48.33	7.0	68.33	34.0	28.0	23.0	82.0	60.0	10.25	30.0	47.07610
075 2	22 1	12.0	3.75	3.75	10.5	3.0	10.0	9.0	60.0	
31.33	12.0	85.5	43.0	25.0	19.0	70.0	43.0	11.25	53.0	38.91908
072 2	24 1	29.0	3.69	3.75	15.0	11.0	16.25	15.0	68.0	
25.08	16.0	55.0	50.0	31.0	25.0	83.0	90.0	20.5	57.0	61.47079
007 2	19 0	13.0	3.42	3.33	9.99	14.0	12.75	5.0	91.0	
1.33	25.0	17.33	42.0	34.0	17.0	57.0	58.0	8.0	74.0	46.11639
052 2	24 0	13.0	2.86	3.0	9.0	10.0	6.0	7.0	91.0	
43.25	9.0	63.25	35.0	21.0	17.0	57.0	45.0	3.75	55.0	39.87869
053 2	28 0	15.0	4.0	4.0	12.0	7.0	17.75	12.0	96.0	
34.58	3.0	58.08	49.0	27.0	25.0	83.0	98.0	19.0	73.0	65.30939
029 2	20 1	7.0	3.16	3.5	7.0	4.0	10.25	10.0	61.0	
31.8	17.0	82.9	43.0	27.0	19.0	63.0	73.0	10.5	57.0	53.31380
110 2	32 0	10.0	3.93	4.0	12.0	12.0	20.0	15.0	78.0	
91.58	2.0	95.0	50.0	19.0	24.0	89.0	85.0	15.0	79.0	49.47519
023 2	20 0	8.0	3.53	3.5	14.0	4.0	15.0	11.0	69.0	
59.0	7.0	70.25	46.0	18.0	19.0	83.0	35.0	6.5	71.0	35.08049

Raw data records for technolgical sequence: electronic engineering

095 3	19 1	14.0	3.66	4.0	12.0	8.0	13.75	17.0	55.0	
28.5	6.0	42.0	37.0	20.0	23.0	77.0	63.0	7.0	54.0	49.36989
094 3	24 1	4.0	3.88	4.0	12.0	6.0	13.5	17.0	40.0	
65.25	6.0	86.83	47.0	10.0	16.0	67.0	74.0	14.75	58.0	55.38049
142 3	18 1	9.0	1.14	1.0	2.0	4.0	15.0	16.0	62.0	
15.33	10.0	21.83	50.0	23.0	19.0	63.0	66.0	22.25	50.0	51.14560
015 3	19 1	9.0	3.27	4.0	8.0	8.0	17.5	9.0	49.0	
68.83	4.0	82.83	47.0	8.0	27.0	90.0	69.0	12.25	68.0	52.92119
018 3	18 0	9.0	2.21	2.67	11.0	8.0	14.0	16.0	54.0	
26.92	10.0	46.16	49.0	16.0	20.0	67.0	69.0	8.5	73.0	52.92119
057 3	18 1	12.0	2.84	3.0	9.0	1.0	17.5	15.0	52.0	
18.83	4.0	84.16	50.0	20.0	23.0	92.0	71.0	18.5	58.0	54.10489
130 3	18 1	7.0	3.47	3.67	11.0	6.0	8.0	12.0	38.0	
24.5	30.0	69.75	42.0	8.0	16.0	70.0	80.0	8.25	46.0	59.43169
137 3	19 1	8.0	3.22	3.33	9.99	8.0	15.0	15.0	64.0	
20.5	23.0	36.08	43.0	20.0	21.0	70.0	71.0	11.75	76.0	54.10439
147 3	32 0	10.0	2.37	2.0	10.0	3.0	8.5	5.0	56.0	
35.0	14.0	58.58	49.0	24.0	1.0	3.0	34.0	13.25	60.0	32.20581
154 3	18 1	14.0	1.84	2.67	8.0	17.0	8.0	14.0	65.0	
30.0	5.0	37.67	45.0	4.0	25.0	93.0	40.0	11.75	62.0	55.75699
062 3	18 1	12.0	2.73	2.67	8.0	20.0	12.75	15.0	40.0	
20.58	16.0	32.0	42.0	22.0	25.0	83.0	46.0	18.25	58.0	39.30820
066 3	19 1	16.0	2.15	3.0	9.0	7.0	15.0	13.0	47.0	
24.42	9.0	38.67	48.0	21.0	21.0	81.0	80.0	16.5	68.0	62.98289
156 3	18 1	8.0	2.15	2.0	6.0	7.0	10.5	10.0	45.0	
31.25	7.0	41.75	44.0	17.0	21.0	70.0	60.0	11.75	75.0	47.59430
158 3	25 1	5.0	2.45	3.0	9.0	7.0	18.75	15.0	64.0	
28.67	19.0	49.0	50.0	20.0	21.0	87.0	86.0	11.75	60.0	62.98289
077 3	28 1	4.0	2.56	2.0	4.0	9.0	14.75	7.0	47.0	
51.5	8.0	68.75	43.0	25.0	17.0	54.0	43.0	12.0	41.0	37.53259
037 3	31 1	5.0	3.53	3.5	14.0	5.0	17.5	18.0	71.0	
22.08	12.0	38.67	40.0	19.0	23.0	77.0	77.0	21.0	59.0	57.65610
073 3	31 1	9.0	2.42	3.0	12.0	15.0	15.75	16.0	49.0	
39.92	4.0	48.67	40.0	18.0	19.0	68.0	63.0	9.0	58.0	49.36989
068 3	27 1	3.0	3.32	3.67	11.0	9.0	11.75	18.0	80.0	
63.5	5.0	72.08	45.0	17.0	22.0	73.0	71.0	8.75	62.0	54.10489
102 3	18 1	7.0	3.43	3.0	9.0	5.0	13.5	12.0	63.0	
31.42	3.0	63.0	31.0	23.0	23.0	77.0	40.0	5.5	43.0	39.30820
125 3	24 1	10.0	2.46	3.0	9.0	15.0	8.5	10.0	69.0	
36.25	6.0	58.75	34.0	18.0	19.0	76.0	63.0	2.0	80.0	49.36989
051 3	22 1	3.0	2.42	2.33	7.0	15.0	8.5	3.0	53.0	
10.67	32.0	32.5	46.0	16.0	7.0	23.0	34.0	4.75	44.0	32.20581
038 3	19 1	4.0	2.46	2.0	6.0	5.0	6.5	12.0	65.0	
26.92	14.0	43.0	28.0	20.0	22.0	78.0	34.0	6.5	27.0	32.20581
059 3	20 1	16.0	3.85	4.0	24.0	6.0	20.0	12.0	72.0	
40.16	4.0	48.16	50.0	16.0	27.0	90.0	80.0	16.75	77.0	59.43169
149 3	20 1	3.0	3.33	3.0	18.0	5.0	17.5	7.0	73.0	
43.83	11.0	62.17	50.0	15.0	21.0	88.0	77.0	17.5	69.0	57.65610
047 3	20 1	14.0	3.72	4.0	24.0	4.0	15.25	17.0	84.0	
37.17	12.0	48.5	50.0	16.0	22.0	88.0	77.0	14.0	62.0	57.65610
020 3	20 1	6.0	2.63	2.5	15.0	12.0	14.0	13.0	49.0	
16.25	12.0	31.0	30.0	19.0	23.0	77.0	51.0	11.25	55.0	42.26749
039 3	41 1	7.0	4.0	4.0	24.0	13.0	14.0	17.0	75.0	
38.08	11.0	55.67	38.0	20.0	23.0	82.0	83.0	14.5	62.0	61.20729
006 3	24 1	13.0	3.34	3.5	21.0	2.0	20.0	18.0	56.0	
19.25	8.0	34.67	48.0	21.0	26.0	87.0	80.0	21.0	73.0	62.98289
050 3	21 1	7.0	3.25	3.75	22.5	9.0	12.75	16.0	56.0	
36.75	12.0	72.17	33.0	33.0	24.0	80.0	51.0	6.75	41.0	42.26749
054 3	24 1	7.0	3.7	4.0	24.0	12.0	4.25	16.0	96.0	
34.83	7.0	55.17	34.0	25.0	24.0	80.0	80.0	6.0	53.0	62.98289

Raw data records for technological sequence: general business management

176 4	21 1	2.0	1.96	4.0	8.0	21.0	9.5	2.0	28.0	
171.3	11.0	203.3	25.0	10.0	10.0	42.0	53.0	5.75	19.0	41.54359
019 4	42 1	9.0	1.6	2.5	5.0	14.0	11.25	4.0	70.0	
20.5	22.0	40.17	47.0	13.0	3.0	10.0	76.0	9.75	71.0	57.86789
116 4	19 0	4.0	2.0	2.0	6.0	6.0	6.0	6.0	72.0	
20.5	17.0	38.42	49.0	18.0	10.0	35.0	60.0	5.0	57.0	46.51790
148 4	22 1	8.0	2.57	3.0	6.0	14.0	8.25	14.0	51.0	
61.5	6.0	97.67	47.0	12.0	15.0	56.0	34.0	6.5	39.0	28.04170
150 4	20 0	4.0	2.11	2.5	5.0	9.0	10.25	3.0	83.0	
8.0	20.0	17.67	41.0	20.0	16.0	53.0	62.0	9.5	22.0	47.93919
063 4	20 0	4.0	2.48	3.0	3.0	14.0	11.75	5.0	63.0	
21.0	9.0	36.92	48.0	20.0	17.0	57.0	73.0	6.75	60.0	55.75609
131 4	20 1	5.0	3.48	4.0	4.0	5.0	11.5	17.0	68.0	
35.75	20.0	71.0	50.0	17.0	20.0	67.0	80.0	11.75	32.0	60.73039
151 4	32 0	14.0	2.93	4.0	8.0	7.0	10.0	8.0	47.0	
32.25	7.0	48.56	50.0	15.0	15.0	75.0	67.0	8.75	58.0	51.49229
153 4	20 0	6.0	2.9	3.0	9.0	4.0	8.5	10.0	61.0	
85.58	11.0	103.7	44.0	20.0	17.0	57.0	65.0	5.0	40.0	50.07109
042 4	20 1	17.0	3.38	4.0	4.0	14.0	15.25	17.0	70.0	
67.5	6.0	73.58	43.0	17.0	26.0	87.0	80.0	9.0	78.0	60.73039
044 4	18 1	6.0	2.93	4.0	4.0	8.0	12.25	13.0	57.0	
37.83	15.0	57.0	47.0	15.0	23.0	81.0	80.0	14.5	59.0	60.73039
128 4	20 1	2.0	2.57	3.0	6.0	11.0	8.25	12.0	50.0	
16.67	11.0	37.08	47.0	30.0	13.0	54.0	70.0	7.0	18.0	53.62419
201 4	23 0	10.0	2.12	3.0	3.0	3.0	7.25	12.0	73.0	
16.58	20.0	37.5	41.0	21.0	12.0	41.0	63.0	10.25	52.0	48.64980
159 4	25 1	7.0	1.86	3.0	3.0	6.0	6.75	8.0	93.0	
57.92	9.0	71.25	17.0	36.0	11.0	37.0	50.0	6.25	79.0	39.41170
160 4	30 0	5.0	2.97	2.0	2.0	4.0	7.25	3.0	59.0	
78.25	14.0	92.33	13.0	23.0	12.0	40.0	63.0	7.25	53.0	48.64980
041 4	29 0	4.0	2.46	2.0	2.0	16.0	6.25	14.0	75.0	
36.83	14.0	51.75	39.0	21.0	18.0	60.0	67.0	6.75	19.0	51.49229
064 4	19 1	9.0	2.48	3.0	3.0	6.0	12.75	7.0	54.0	
23.83	13.0	45.83	49.0	14.0	22.0	79.0	77.0	10.75	61.0	58.54859
100 4	28 1	10.0	2.23	3.0	3.0	10.0	9.5	11.0	72.0	
37.5	11.0	54.3	35.0	24.0	10.0	33.0	57.0	7.0	35.0	44.36609
033 4	20 0	4.0	2.76	3.0	3.0	9.0	9.5	15.0	68.0	
71.58	4.0	83.0	47.0	18.0	20.0	74.0	47.0	4.25	16.0	37.27979
027 4	20 1	12.0	3.35	4.0	8.0	4.0	10.5	10.0	74.0	
46.08	15.0	54.33	44.0	28.0	25.0	83.3	83.0	5.0	60.0	62.86229
117 4	20 0	6.0	3.0	3.0	3.0	10.0	10.0	4.0	71.0	
50.92	6.0	74.67	35.0	13.0	11.0	42.0	70.0	6.0	69.0	53.62419
123 4	19 1	7.0	1.83	0.0	0.0	0.0	10.0	16.0	95.0	
41.83	11.0	59.75	18.0	40.0	9.0	30.0	33.0	3.5	20.0	27.33101
012 4	19 1	10.0	1.84	2.5	5.0	10.0	4.0	1.0	44.0	
17.5	18.0	37.58	48.0	26.0	4.0	13.0	43.0	6.5	28.0	34.43730
014 4	21 0	6.0	3.37	3.0	3.0	6.0	12.0	15.0	91.0	
41.58	6.0	90.58	47.0	16.0	19.0	83.0	77.0	10.75	37.0	58.54859
172 4	19 1	3.0	1.79	3.0	3.0	10.0	10.75	11.0	80.0	
66.92	6.0	78.25	42.0	16.0	20.0	67.0	67.0	12.0	50.0	51.49229
113 4	24 0	4.0	2.35	2.0	4.0	18.0	9.0	6.0	69.0	
30.0	10.0	42.75	46.0	28.0	9.0	30.0	47.0	6.5	66.0	37.27979
143 4	21 1	6.0	2.3	1.0	1.0	4.0	4.5	13.0	71.0	
76.33	8.0	88.42	40.0	29.0	13.0	59.0	67.0	5.25	29.0	51.49229
079 4	22 0	6.0	3.82	4.0	4.0	5.0	14.5	17.0	73.0	
17.25	15.0	39.42	42.0	28.0	22.0	79.0	83.0	14.75	56.0	62.86229
076 4	39 0	3.0	2.43	2.5	5.0	10.0	5.0	3.0	90.0	
34.08	4.0	43.0	42.0	33.0	10.0	33.0	73.0	6.75	60.0	55.75609
067 4	23 1	11.0	3.56	3.75	3.75	6.0	10.0	5.0	57.0	
40.91	18.0	44.41	49.0	18.0	24.0	80.0	80.0	17.5	78.0	60.73039

Raw data records for technological sequence: medical laboratory

046 5	20 0	6.0	1.06	3.5	7.0	4.0	2.75	0.0	61.0	
91.58	2.0	98.0	41.0	27.0	13.0	56.0	55.0	4.75	42.0	50.30919
093 5	26 1	18.0	2.86	3.5	7.0	6.0	6.5	5.0	44.0	
68.25	7.0	69.08	41.0	10.0	10.0	42.0	62.0	11.75	64.0	54.78270
149 5	20 0	6.0	2.5	2.67	8.0	9.0	12.5	12.0	51.0	
45.75	9.0	66.75	42.0	23.0	20.0	74.0	43.0	6.5	44.0	42.64049
134 5	24 0	8.0	2.3	3.0	3.0	10.0	1.75	8.0	96.0	
16.5	24.0	32.42	49.0	29.0	17.0	54.0	25.0	2.75	32.0	31.13741
121 5	24 0	2.0	2.88	3.5	7.0	8.0	12.75	13.0	90.0	
80.5	4.0	62.6	48.0	27.0	20.0	71.0	15.0	0.0	8.0	24.74681
136 5	32 0	4.0	3.67	3.5	7.0	9.0	13.0	15.0	55.0	
76.58	4.0	84.58	50.0	19.0	24.0	83.0	62.0	11.75	43.0	54.78270
048 5	32 0	7.0	3.93	4.0	8.0	7.0	12.25	17.0	55.0	
59.09	8.0	67.75	50.0	24.0	25.0	86.0	65.0	14.0	65.0	56.69980
133 5	20 0	6.0	2.13	3.5	7.0	7.0	8.75	6.0	93.0	
22.5	0.0	30.3	48.0	14.0	16.0	53.0	62.0	7.5	55.0	54.78270
084 5	26 0	4.0	3.27	3.0	3.0	5.0	16.5	9.0	90.0	
36.5	12.0	56.25	37.0	16.0	21.0	88.0	48.0	13.0	20.0	45.83580
080 5	19 0	8.0	2.28	4.0	4.0	11.0	12.5	4.0	84.0	
46.91	5.0	56.75	50.0	32.0	16.0	53.0	68.0	13.5	73.0	58.61699
107 5	21 1	9.0	2.85	3.0	6.0	12.0	14.5	15.0	58.0	
13.75	18.0	29.0	45.0	14.0	16.0	57.0	55.0	12.25	56.0	50.30919
103 5	22 0	7.0	2.97	4.0	8.0	8.0	10.0	14.0	80.0	
13.5	12.0	33.75	50.0	27.0	19.0	63.0	55.0	12.75	80.0	50.30919
104 5	19 0	6.0	2.22	3.0	6.0	19.0	12.75	10.0	72.0	
50.41	9.0	69.83	34.0	26.0	20.0	67.0	48.0	9.0	78.0	45.83580
105 5	21 0	9.0	3.32	3.5	7.0	7.0	12.5	15.0	96.0	
25.41	9.0	34.67	44.0	30.0	30.0	100.	60.0	13.25	45.0	53.50449
069 5	21 0	4.0	3.42	4.0	4.0	12.0	15.25	17.0	92.0	
28.87	6.0	40.64	49.0	19.0	19.0	63.0	73.0	9.25	52.0	61.81229
174 5	19 0	7.0	3.35	4.0	4.0	14.0	17.5	16.0	75.0	
61.33	0.0	61.33	45.0	20.0	28.0	93.0	63.0	9.25	51.0	55.42169
175 5	21 0	6.0	3.26	4.0	4.0	1.0	15.5	14.0	91.0	
61.17	3.0	66.09	46.0	27.0	24.0	92.0	58.0	11.0	60.0	52.22639
166 5	18 0	7.0	3.87	4.0	4.0	10.0	13.75	14.0	67.0	
80.54	3.0	87.0	41.0	29.0	20.0	83.0	88.0	10.5	39.0	71.39828
003 5	21 0	6.0	2.68	4.0	4.0	8.0	15.0	13.0	66.0	
53.58	9.0	67.17	38.0	17.0	20.0	67.0	65.0	10.5	51.0	56.69980
108 5	19 0	11.0	3.76	4.0	8.0	6.0	17.5	13.0	62.0	
35.08	9.0	42.58	50.0	14.0	24.0	80.0	65.0	16.75	63.0	56.69980
025 5	21 0	6.0	1.68	2.5	5.0	21.0	10.75	2.0	64.0	
24.17	14.0	41.75	47.0	20.0	14.0	47.0	40.0	7.75	56.0	40.72330
170 5	18 0	10.0	3.12	3.0	3.0	10.0	6.0	7.0	73.0	
17.85	15.0	28.91	49.0	21.0	20.0	71.0	50.0	1.75	36.0	47.11389
168 5	20 0	12.0	3.11	4.0	8.0	11.0	13.5	15.0	64.0	
116.5	0.0	140.3	47.0	34.0	21.0	84.0	58.0	13.0	42.0	52.22639
167 5	21 0	11.0	2.71	3.5	7.0	9.0	17.5	10.0	96.0	
62.5	10.0	79.0	47.0	34.0	14.0	47.0	68.0	15.75	65.0	58.61699
185 5	20 0	5.0	2.64	3.0	6.0	3.0	12.75	16.0	93.0	
32.58	10.0	42.83	41.0	30.0	20.0	67.0	35.0	4.0	18.0	37.52800
165 5	23 0	11.0	3.82	4.0	8.0	22.0	18.75	15.0	92.0	
36.67	5.0	42.33	46.0	31.0	21.0	70.0	58.0	10.25	46.0	52.22639
190 5	23 1	6.0	3.11	3.5	7.0	5.0	15.0	11.0	60.0	
31.9	9.0	34.8	43.0	17.0	13.0	76.0	38.0	12.5	12.0	34.44519
177 5	21 1	4.0	2.45	3.0	9.0	16.0	11.5	7.0	80.0	
102.5	9.0	128.5	39.0	33.0	17.0	63.0	23.0	6.75	59.0	29.85931
173 5	20 1	9.0	2.58	4.0	8.0	12.0	15.0	14.0	27.0	
47.83	8.0	66.83	50.0	13.0	19.0	70.0	73.0	13.25	53.0	61.81229
187 5	30 0	4.0	2.83	3.5	7.0	6.0	15.25	4.0	67.0	
60.9	4.0	70.5	50.0	13.0	14.0	73.0	58.0	14.5	34.0	52.22639

Raw data records for technological sequence: nursing

040 6	32 0	11.0	3.72	0.0	0.0	11.0	13.0	10.0	46.0	
49.42	12.0	37.08	50.0	22.0	20.0	67.0	90.0	17.0	39.0	60.56099
092 6	29 0	5.0	3.44	0.0	0.0	11.0	14.25	14.0	55.0	
38.33	9.0	55.66	24.0	25.0	21.0	80.0	76.0	10.75	75.0	50.23830
041 6	24 1	12.0	3.27	0.0	0.0	11.0	16.25	16.0	72.0	
47.16	9.0	56.08	46.0	30.0	25.0	86.0	96.0	22.0	51.0	65.01360
144 6	36 0	4.0	3.08	4.0	4.0	12.0	20.0	16.0	54.0	
30.5	11.0	44.75	50.0	13.0	17.0	57.0	72.0	14.0	30.0	47.28329
112 6	24 0	5.0	3.15	0.0	0.0	14.0	15.5	8.0	47.0	
62.75	4.0	67.41	48.0	28.0	20.0	95.0	84.0	11.75	14.0	56.14839
049 6	28 0	4.0	3.64	0.0	0.0	7.0	6.75	6.0	77.0	
41.5	7.0	49.91	35.0	30.0	16.0	55.0	74.0	6.75	30.0	48.76079
010 6	23 0	10.0	3.01	0.0	0.0	2.0	12.75	3.0	40.0	
107.3	4.0	107.8	41.0	19.0	17.0	77.0	78.0	11.75	58.0	51.71579
013 6	25 0	3.0	3.53	3.0	3.0	9.0	11.0	14.0	67.0	
59.58	5.0	70.0	34.0	26.0	23.0	84.0	82.0	14.25	32.0	54.67090
017 6	22 0	4.0	3.1	0.0	0.0	5.0	10.75	14.0	74.0	
55.58	11.0	75.75	50.0	25.0	20.0	69.0	62.0	12.0	27.0	39.89560
133 6	40 0	5.0	1.98	4.0	4.0	6.0	12.0	3.0	74.0	
91.58	7.0	134.4	23.0	24.0	18.0	62.0	50.0	2.25	44.0	31.03041
056 6	21 0	4.0	2.58	2.0	2.0	5.0	15.25	11.0	53.0	
30.41	12.0	64.58	48.0	9.0	18.0	67.0	82.0	7.75	26.0	54.67090
043 6	24 0	6.0	3.04	0.0	0.0	8.0	17.5	9.0	68.0	
17.67	15.0	45.17	47.0	35.0	15.0	65.0	94.0	6.5	27.0	63.53609
106 6	19 0	10.0	2.29	2.0	2.0	13.0	0.75	3.0	58.0	
28.92	28.0	72.17	47.0	31.0	8.0	38.0	76.0	2.0	45.0	50.23830
083 6	28 0	3.0	3.73	4.0	4.0	13.0	12.0	7.0	96.0	
58.5	3.0	66.5	50.0	30.0	15.0	50.0	72.0	6.25	41.0	47.28329
155 6	24 0	4.0	2.07	3.0	3.0	5.0	4.75	4.0	61.0	
31.67	7.0	46.5	17.0	12.0	15.0	60.0	54.0	2.0	34.0	33.96550
074 6	23 0	3.0	3.63	4.0	4.0	4.0	12.75	9.0	70.0	
25.33	14.0	42.25	39.0	22.0	18.0	67.0	58.0	3.5	29.0	33.96550
066 6	38 0	4.0	3.18	4.0	4.0	3.0	11.75	3.0	39.0	
48.83	16.0	66.17	48.0	22.0	13.0	43.0	60.0	9.75	9.0	38.41809
105 6	18 0	13.0	2.31	0.0	0.0	16.0	12.75	13.0	81.0	
24.5	13.0	37.75	43.0	22.0	25.0	83.0	92.0	10.5	77.0	62.05859
104 6	34 0	3.0	3.17	4.0	4.0	2.0	12.25	2.0	63.0	
23.67	13.0	42.08	36.0	26.0	20.0	67.0	88.0	9.75	20.0	59.10349
101 6	26 0	4.0	2.85	4.0	4.0	11.0	11.75	10.0	78.0	
30.09	10.0	57.34	47.0	33.0	20.0	67.0	80.0	8.75	37.0	38.41809
016 6	19 0	9.0	2.81	0.0	0.0	11.0	12.5	2.0	96.0	
36.33	9.0	43.08	48.0	27.0	21.0	70.0	72.0	11.25	61.0	47.28329
035 6	27 0	5.0	3.58	0.0	0.0	7.0	11.5	7.0	58.0	
41.17	7.0	54.08	45.0	48.0	17.0	89.0	64.0	5.75	22.0	41.37309
161 6	48 0	2.0	2.61	3.0	6.0	8.0	5.0	2.0	70.0	
34.91	33.0	91.92	47.0	24.0	6.0	40.0	84.0	1.75	59.0	56.14839
061 6	39 0	4.0	3.43	0.0	0.0	6.0	11.25	1.0	48.0	
133.1	4.0	147.8	24.0	20.0	17.0	81.0	68.0	5.25	26.0	59.10349
081 6	31 0	10.0	3.33	0.0	0.0	7.0	10.5	13.0	77.0	
112.2	1.0	114.6	47.0	35.0	21.0	81.0	84.0	11.5	52.0	56.14839
045 6	20 0	18.0	2.88	0.0	0.0	2.0	10.75	8.0	75.0	
86.08	0.0	86.08	50.0	31.0	19.0	73.0	90.0	8.75	58.0	60.56099
119 6	22 0	5.0	3.55	0.0	0.0	8.0	7.5	15.0	86.0	
36.33	11.0	64.17	50.0	34.0	21.0	88.0	78.0	10.25	34.0	51.71579
124 6	21 0	7.0	2.96	0.0	0.0	15.0	13.5	4.0	83.0	
14.83	1.0	26.58	50.0	27.0	18.0	72.0	94.0	9.25	56.0	63.53609
021 6	26 1	5.0	2.86	0.0	0.0	7.0	15.0	17.0	74.0	
22.0	11.0	37.17	49.0	34.0	15.0	71.0	72.0	8.75	15.0	47.28329
118 6	27 0	4.0	3.01	0.0	0.0	8.0	14.25	14.0	57.0	
41.75	11.0	51.33	49.0	32.0	20.0	77.0	74.0	18.5	38.0	48.76079

APPENDIX G

MULTIVARIATE ANALYSIS OF VARIANCE SUMS OF SQUARES AND CROSS PRODUCTS MATRICES (SSCP)--BETWEEN GROUPS AND WITHIN GROUPS

Table 38

H (Type IV SS&CP Matrix for Technological Sequence)

	ANSIE	FDS	GEFT	IPR	MFFT1	MFFT2	SWI	STP
ANSIE	42.45							
FDS	-31.38	461.28						
GEFT	6.62	386.07	577.83					
IPR	279.43	-360.41	-528.77	3242.60				
MFFT1	163.11	-76.10	-719.20	3170.94	4254.74			
MFFT2	-25.92	-163.67	-13.37	-345.83	-475.08	262.09		
SWI	29.08	318.04	225.77	35.67	162.94	-254.96	390.69	
STP	-26.02	1.60	-486.33	565.20	1408.59	-255.33	177.73	1067.89

E (Error SS&CP Matrix)

	ANSIE	FDS	GEFT	IPR	MFFT1	MFFT2	SWI	STP
ANSIE	3406.10							
FDS	-69.22	2672.76						
GEFT	-22.70	1152.61	3859.70					
IPR	-35.13	13.73	1814.60	37953.20				
MFFT1	-371.98	1202.26	-82.18	-13632.91	112177.76			
MFFT2	168.73	-1053.62	-1032.60	-859.93	-14420.31	7018.63		
SWI	-117.40	1682.47	1005.70	-204.90	-5538.17	143.73	9912.03	
STP	112.90	-193.83	396.47	6631.77	-2377.54	503.37	-454.27	8429.10

APPENDIX H

COMPLETE MULTIVARIATE ANALYSIS OF VARIANCE TABLE AND COMPUTER PRINTED ANOVA TABLES

Table 39

Complete Multivariate Analysis of Variance Summary (n = 180)

Source of Variation	Sums of Squares and Cross Products (SSCP)	Degrees of Freedom	MANOVA Wilks' Λ	MANOVA F ratio (prob.)	Degrees of Freedom	ANOVA Variable	ANOVA F ratio (prob.)
Technology Sequence (between gps)	H = Type IV SS&CP Matrix for Technology (see Appendix H)	40, 730	0.544	2.74** (0.0001)	5	ANSIE	0.43 (0.8246)
						FDS	6.01** (0.0000)
						GEFT	5.21** (0.0002)
						IPR	2.97* (0.0133)
						MFFT1	1.32 (0.2578)
						MFFT2	1.30 (0.2663)
						SWI	1.37 (0.2372)
Error (within gps)	E = Error SS&CP Matrix (see Appendix H)				174	STP	4.41** (0.0008)
Total	T = Total SS&CP Matrix						

* Significant at $p < 0.05$
** Significant at $p < 0.01$

Table 40

Univariate Analysis of Variance Summary for Dependent Variable: ANSIE

ANALYSIS OF VARIANCE TABLE					
SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	42.4500	5	8.4900	0.43	0.8246
WITHIN GROUPS	3406.0862	174	19.5752		
TOTAL	3448.5361	179			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 174		0.15	0.9796

Table 41

Univariate Analysis of Variance Summary for Dependent Variable: FDS

ANALYSIS OF VARIANCE TABLE					
SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	461.2749	5	92.2550	6.01	0.0000
WITHIN GROUPS	2672.7480	174	15.3606		
TOTAL	3134.0229	179			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 174		1.77	0.1207

Table 42

Univariate Analysis of Variance Summary for Dependent Variable: GEFT

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	577.8269	5	115.5654	5.21	0.0002
WITHIN GROUPS	3859.6860	174	22.1821		
TOTAL	4437.5117	179			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 174		1.32	0.2587

Table 43

Univariate Analysis of Variance Summary for Dependent Variable: IPR

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	3242.5764	5	648.5151	2.97	0.0133
WITHIN GROUPS	37953.1250	174	218.1214		
TOTAL	41195.6992	179			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 174		1.01	0.4129

Table 44

Univariate Analysis of Variance Summary for Dependent Variable: MFFT1

ANALYSIS OF VARIANCE TABLE					
SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	4254.7461	5	850.9492	1.32	0.2578
WITHIN GROUPS	112177.312	174	644.6970		
TOTAL	116432.000	179			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 174		1.74	0.1275

Table 45

Univariate Analysis of Variance Summary for Dependent Variable: MFFT2

ANALYSIS OF VARIANCE TABLE					
SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	262.0942	5	52.4188	1.30	0.2663
WITHIN GROUPS	7018.6055	174	40.3368		
TOTAL	7280.6992	179			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 174		0.80	0.5510

Table 46

Univariate Analysis of Variance for Dependent Variable: SWI

ANALYSIS OF VARIANCE TABLE					
SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	390.6951	5	78.1390	1.37	0.2372
WITHIN GROUPS	9912.0078	174	56.9656		
TOTAL	10302.6992	179			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 174		2.55	0.0297

Table 47

Univariate Analysis of Variance for Dependent Variable: STP

ANALYSIS OF VARIANCE TABLE					
SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	TAIL PROBABILITY
BETWEEN GROUPS	1067.8992	5	213.5798	4.41	0.0008
WITHIN GROUPS	8429.1094	174	48.4431		
TOTAL	9497.0078	179			
LEVENE'S TEST FOR EQUAL VARIANCES		5, 174		1.25	0.2864